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Abstracts Bulletin

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Related to the Silicate Industries

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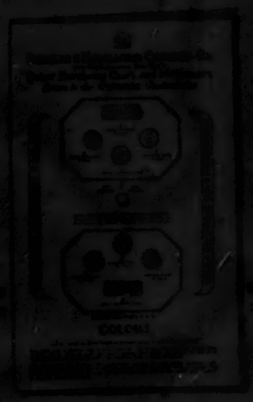

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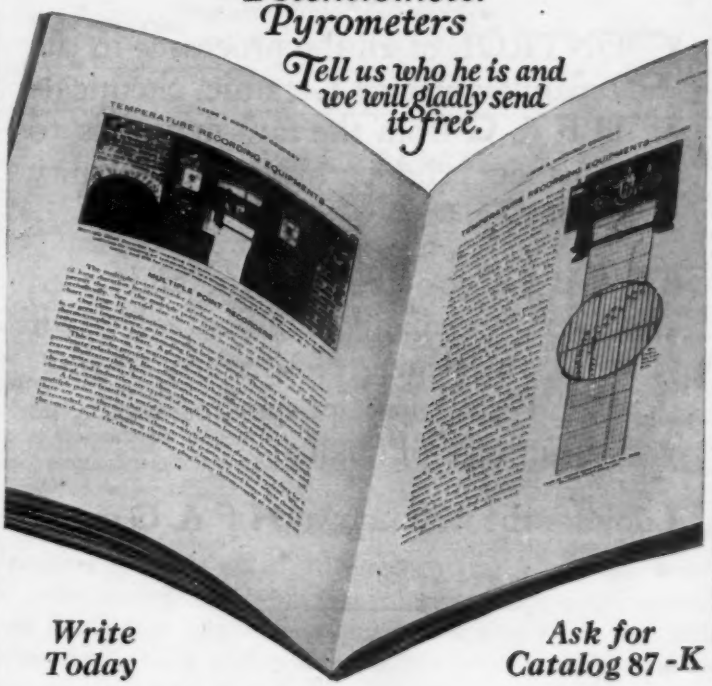

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ORIGINAL PAPERS

NOTES ON SHAPE CONSTRUCTION[1]

BY FREDERICK H. RHEAD

ABSTRACT

The lines of development of a course for training ceramic artists, who are very much in demand, are outlined. Ceramic shape design for quantity production involves a study of factory processes, product specifications, both consumer's and factory, and manufacturing specifications. Examples of commercial designing are demonstrated, using drawings of a series of glass designs as illustrations for various points made. The filing of research studies in design, relation of shapes to product specification, and product development are discussed. The difference between the art engineer and the craftsman is pointed out.

Introduction

The purpose of these notes is to present to the manufacturer and ceramic artist some idea of what is involved in shape construction and design as applied to quantity production and to state the author's opinion on the training and capacity of the ceramic artist required to meet the artistic requirements in modern ceramic productions.

The development of the ceramic industry in this country has reached that stage where the decorative and ornamental element is playing a more important part in the successful marketing of ceramic products, and as a result, organization activities are slowly but surely being adjusted to meet these entirely new requirements.

Many of these requirements have not been clearly defined or even generally recognized, hence progress has been slow. The manufacturers and the available artists are unable to discuss the possibilities from a common viewpoint, or to direct the decorative productive channels

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Detroit, Mich., Feb., 1927. (Art Division.)

according to the dictates of fashion and the market possibilities. Ceramic art is not yet a recognized factory organization activity.

As has been previously stated by several writers, most of the available ceramic decorators, designers, or artistic whatnots are more or less individualists. As a class they lack knowledge and experience in many of the essential business and art fundamentals. On the other hand the manufacturer, most often without adequate practical art resources, assumes the rôle of art director. This makes the job of both the artist and the manufacturer very difficult, if not hopeless, because while the manufacturer may be able to select and dictate, he possesses no ability to create, and the artist does not possess the training or the necessary facilities to produce wares of artistic merit.

Large scale production demanded and obtained the automatic jigger, the glaze machine, the hydraulic press, the tunnel kiln, and other new means of economy in manufacturing. It is now demanding an adequate art organization fully capable of creating to meet the constantly changing demands. The art requirements and possibilities are so large in most ceramic industries that there must be a new ceramic profession involving entirely new courses of instruction, a new type of instructor, and a new type of student before art facilities in ceramics are commensurate with the mechanical facilities for large scale production of artistic ware.

The university graduate entering this new profession will be as different from the present type of ceramic decorator as the present day ceramic technologist is different from the empiric glaze mixer.

The ceramic engineer is concerned with plant design and equipment, preparation of materials, and factory operation; the ceramic technologist will study materials, mixtures, and process control; and the new ceramic artists will direct the creation and production of shapes and decorations of specific quality and for specific purposes. With a technical staff comprised of a ceramic engineer, technologist, and artist, a manufacturer will be in position to produce ware that will meet any market requirement.

When the manufacturer will have available for employment the sort of ceramic artist here suggested he can be assured of types of shapes (aside from their sales value) best suited to his particular manufacturing conditions, and which can be manufactured with a minimum of loss and at a cost within particular market price range. He can be assured that his shapes are skilfully designed, and not merely superficially pleasing to the person ignorant in art matters. If the trend of public taste in decoration is toward any particular period such as Spanish, Italian, or French, he can be assured that his art engineer will

FIG. 1.

meet specifications with authentic examples. If the manufacturer is interested in developing an individual American type of art, or any other individual class of decoration he will have an organization which will produce results.

Training Ceramic Artists

The urgent need for this new ceramic profession is recognized by the more progressive manufacturers. On this there is a very general agreement but in regard to the type of university course essential to the training of a ceramic artist, there may be a serious conflict of opinion. While a well-rounded technical knowledge will be of material assistance to the art man, he cannot afford to acquire this at the expense of his art training. He can obtain technical assistance in the plant while he

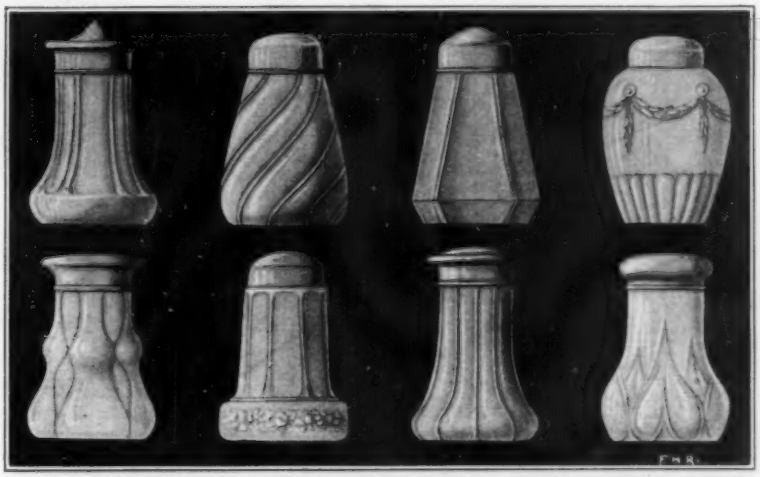

FIG. 2.

may never have the opportunity to acquire fundamental art knowledge after he has left school. Although it is very difficult to state how much technical work the students should do while in school, there is no doubt whatever that he cannot have too much work in art.

A ceramic art course should include instructions in the technical, practical, and commercial branches, but they should not occupy more than 30% of the available school period. With 70% of a student's school period available for art instruction, we find that the art course should be developed about as follows:

Mechanical drafting (working drawings for shapes, models, etc.), 10%
Ornamental drafting (historical modern ornament), 10%
Shape designing, 15%
Designing and decorating, 15%
Block and casing, model making, practical processes, 20%
Engraving, decalcomania, 5%
Decorative processes 25%

As this paper deals with shape construction, which this suggested program shows as occupying 15% of the art course period, a brief survey of the remaining essential subjects will quickly show that the ceramic art student can ill afford to spend more than 30% of his school period on technical work.

What Ceramic Design Involves

Ceramic shape designing involves something more than the making of a pencil or water-color sketch of a ceramic shape. Almost any art student or craft worker can make an attractive sketch for a vase or bowl, and most amateurs can make the finished product by the various methods found practical in schools and in studios. Very few de-

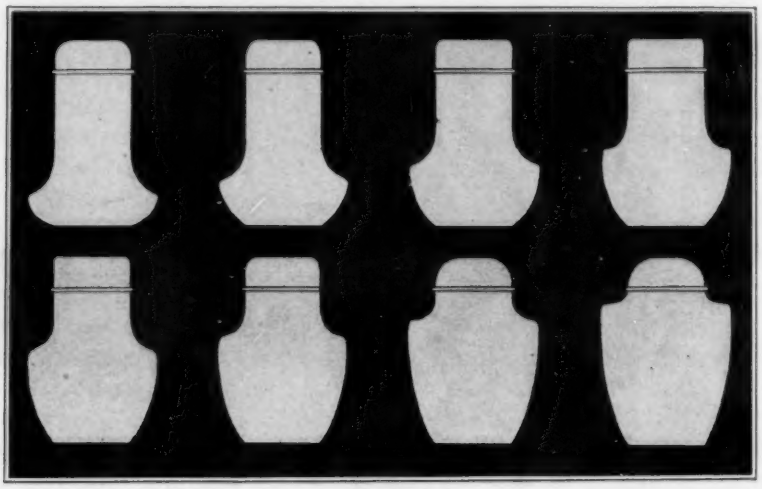

FIG. 3.

signers, however, can make a finished design and working drawing that embodies the necessary specifications for quantity production.

Factory Process Utilitarian products must have commercial value and at the same time must be of a type suitable for the particular process employed in the plant. The manufacturing conditions must be studied. Every pottery has its possibilities and limitations. Each plant is equipped to produce only in certain ways. A certain process in one plant is more highly developed than is the same process in another factory. Modeling and mold making must be studied in relation to the local production methods and conditions. If the shape designer of pottery is ignorant of industrial kiln placing and firing and is not familiar with practical processes, he is working under a serious handicap.

Product Specifications

Many ceramic products are made to specifications other than art and unless the shape designer can meet these, he will be unable to produce a practical design. These specifications may be divided broadly into two groups: (1) consumers' specifications, and (2) factory specifications. The consumers' specifications cover the finished product ready for the market, while the factory specifications refer to the various manufacturing details, such as the type of body and glaze, method of manufacture, size, color, and decoration, and incidently, all of those factors which contribute to a satisfactory product at a minimum of production loss and with satisfactory sales profit.

Manufacturing Specifications

Practically all of the consumers' design specifications are merely sketches showing the general appearance of the article desired. There are no accompanying sketches and data showing the type of mold, manufacturing process, type of material, etc. Yet these must be provided before the article can be manufactured.

When a design is accepted and before it is put into production, the body, glazes, colors, and decorating processes must be specified. The shape must be modeled to a definite contraction scale and an actual size drawing of the model prepared.

In many shapes, particularly those made at high temperature, there are strains which alter the regular contraction allowance, and when the product must be made within narrow variation limits it requires a high degree of skill and a thorough knowledge of the various processes in order to produce an acceptable result.

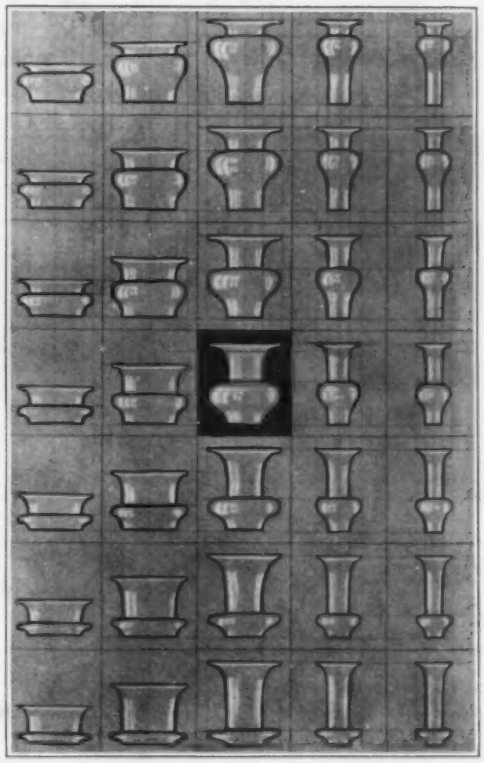

FIG. 4.

Examples of Commercial Designing

In order to demonstrate what is involved in getting out a series of designs for a particular product, I obtained a group of glass shapes from Francis C. Flint through the courtesy of the Hazel-

Atlas Glass Company. These were selected because they were fairly representative of commercial production on a large scale and of a type of production offering perhaps fewer possibilities for artistic originality than any other ceramic production.

In looking over the group of shapes, I have selected a commercial salt shaker as a typical example. This is a small article about three inches high and one and one-half inches wide. It is blown in a two-, three-, or four-part mold, depending upon the amount of relief in the design. As a four- and three-part mold product is more expensive than ware made in two parts, it is obvious that in cheaper ware the factory specifications will require a design which can be made in two parts.

There is no attempt here to suggest new designs; the idea is to show what is involved in making drawings for commercial ceramic production in such instances where a glass manufacturer requiring one million salt shakers per year, is planning to add a third shape which will possibly replace the less satisfactory of the other two.

Now it is obvious that the designer must recognize not only present conditions of manufacturing, but he must bear in mind that the new shapes are additions to the present line. The existing types of designs and manufacturing processes must not be changed to the extent that the cost or sales value will be affected. The designer must also be thoroughly familiar with the particular market if his new creations are to be immediately acceptable to the wholesale trade and finally to the purchasing public. Consequently it is obvious that in this instance there can be no radical departure from the type of design already cataloged by the employing manufacturer.

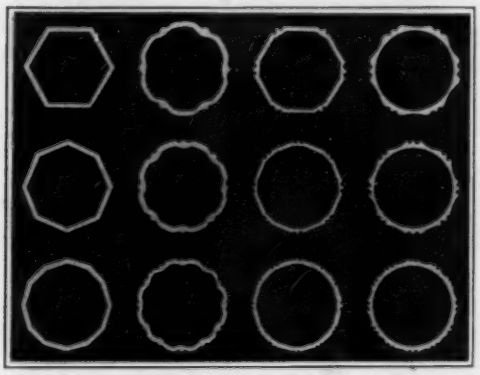

FIG. 5.

Glass Salt Shaker

The salt shaker in Fig. 1 is not manufactured primarily as a work of art; it is merely an article of utility. Obviously it is designed by a practical glass workman, but the fact that it is sold in large quantities proves that it meets consumers' specifications. The sketches show what the present day designer would do to meet a more critical market in inexpensive glass salt shakers. The designer naturally would study similar products of other manufacturers, and weigh in the success of these with the products of his own company. He would review the introduction and development of this particular article. He would also

take into consideration the existing fashions and popular styles. If there should exist a fashion or craze for cut-glass, he would probably make a design approximating cut-glass effects. Or on account of the vogue for early American glass, the designer would study the various Stiegle shapes.

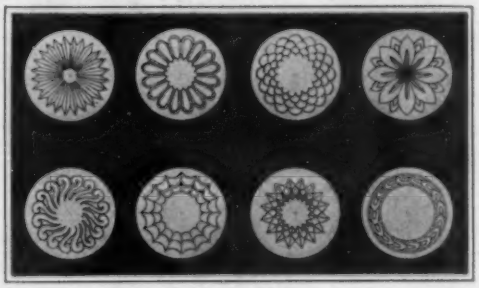

FIG. 6.

These would be the designer's thoughts when preparing a series of sketches. He would then make a few drawings or shapes, such as those shown in Fig. 2.

The first shape in Fig. 2 is a corrected version of the one in Fig. 1. This shape is more carefully developed, the spacing of the flutes and the base of the shape are more carefully drawn. A conservative critic is less likely to find fault with this corrected version, although to the less critical person it differs but little from the original.

The second shape is a suggestion for a spiral flute along the lines of the Stiegle glass previously mentioned. The third shape is hexagonal with a slightly convex flute and concave sides. This is a more severe type of design which would be attractive in contrast to a more ornate and heavily modeled shape. Shape 4 is a plain oviform with a festooned

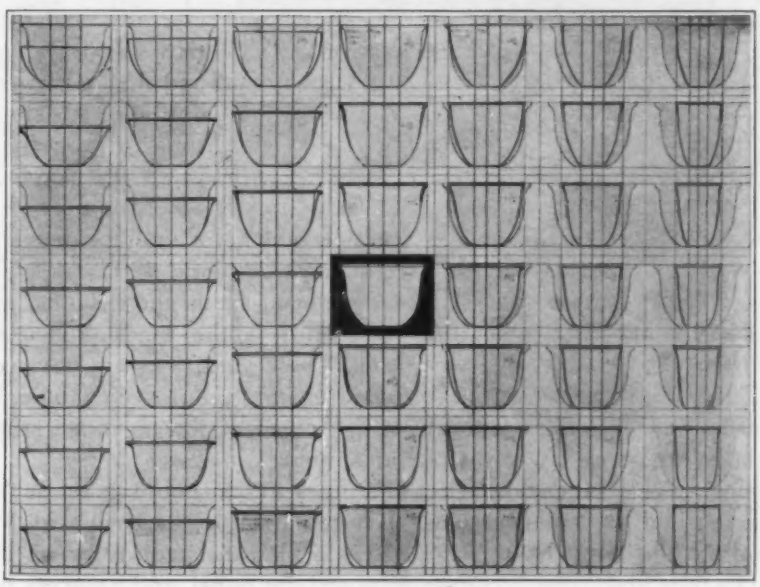

FIG. 7.

wreath and slightly fluted at the base. Unless this shape is made rather small in size it is too rounded and bulky for a serviceable salt shaker. Shape 5 again recalls the somewhat heavily fluted types of some of the Stiegle and early blown glass. Shape 6 is a slightly fluted form with a fruit border at the base. Shape 7 is another variation of No. 1, the flutes being continued to the base of the shape. Shape 8 is a plain shape with a leaf design in low relief.

All these shapes can be made in a two-part mold if the flutes and other decorations are not too high in relief.

As glass is transparent, interesting effects may be obtained with comparatively unbroken surfaces. For instance, the spiral flute on the shape in Fig. 2 is seen in reverse on the other side of the shape. Consequently the designer must recognize that he is dealing with a transparent material offering many possibilities not present in other ceramic ware.

File of Research Studies in Design

A designer permanently connected with a glass concern would no doubt have any number of sketches made from time to time, and he would also have on file considerable data covering this particular article.

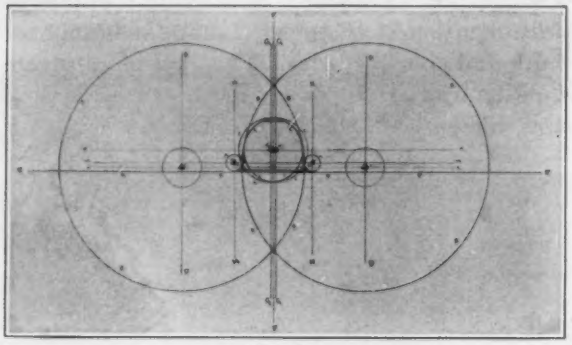

FIG. 8.

The designing of a new shape is too often a last minute effort and where there is no art organization, the manufacturer has no ready-made selection to draw upon and the designer is not allowed enough time to properly develop the shape and decoration. There are many possibilities in shape construction which can only be developed by consistent application and careful research work.

Figure 3 is a series of shapes developed from the original glass example. The only structural difference is the gradual elevation of the widest diameter near the base. These variations are not necessarily improvements over the original example, but such studies are as necessary in connection with shape construction as range studies in glazes are necessary to the technical men.

Another very important series of studies which should be made from time to time are cross-sections of ceramic shapes as shown in Figs. 4 and 5. The top row of Fig. 5 shows a plain hexagon followed by a convex flute and panel, a convex flute and flat panel, and a convex flute

with a concave panel. The second row shows octagonal shapes and the bottom row shows twelve-sided forms.

It is obvious that a number of these cross-sections could not be made in a two-part mold, but it is a simple matter to make accurate geometrical drawings in order to determine the possibilities and limitations of a two-part mold.

Figure 6 shows rough sketches of variations for the base of glass shapes. A large number of commercial glass shapes are made with a base similar to this first sketch.

If I were a glass manufacturer, I should want a distinctive finish on the bases of my wares and I should select a design which would be in character with the shape. The transparency of glass offers many possibilities, and I see no reason why different manufacturers should be satisfied with the same type of finish at the base.

Relation of Shape to Product Specification

Figure 7 shows a study of the relation of shape to thermal resistance in chemical porcelain crucibles. The various shapes were carefully designed and fabricated for purpose of testing. The diameter of the low shapes and the height of the narrow shapes were constant with the gradual diminishing of the base curve. The flange varied consistently with the diameter of the top of the shape. The test pieces were made under similar conditions. It was found that the center shape with the black background had better thermal resistance properties than any of the other shapes.

Figure 8 shows a typical geometrical analysis of these shapes. The crucible shape thus developed is shown inverted at the center of the drawing.

FIG. 9.

Product Development

Figure 9 is an example of an average working drawing for the modeler. The drawing is not complete because it was decided to model the

plain shape in plaster according to the section diagrams and then complete the design over the plaster form. Where the necessary skilled help is available it is not necessary to make elaborate detailed drawings although this is always advisable for record purposes. But where there is a lack of efficient direction and practical skill, it is impossible to execute satisfactory work without complete detailed drawings.

In Fig. 10 are rough sketches showing possibilities in ordinary utilitarian stoneware. The stoneware bowl illustrated in the upper left-hand corner (Fig. 10) is the customary crock. These bowls are fired without saggers. The glaze is scraped off the edge underneath the flange and the ware is stacked up in the kiln in the manner shown in the illustration.

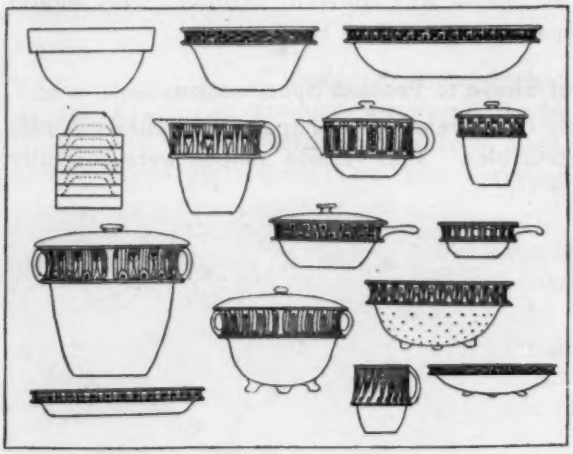

FIG. 10.

Whatever the shape may be in this class of ware, it is essential that it be manufactured and fired in the same manner as the plain bowls. The designs are incised on the model, so aside from this extra though negligible cost when quantity production is considered, this class of ware would cost no more to make than the ordinary plain stoneware product.

Figure 11 gives the different stages in mold making for a porcelain medicine cabinet. Number 1 is the plaster model. This piece is twenty-six inches high and the two shelves are cast in the cabinet. In number 2 the cabinet is inverted on a level mold table and covered with plaster. Number 3 shows the back of the model incased in plaster. Number 4 shows the plaster slabs adjusted for the side cores. Number 5 shows the side cores in position when the plaster has been poured and the slabs removed. Number 6 shows the cores as completed and the block mold finished when this has been covered with plaster. Number 7 shows the completed block molds with the model removed. Numbers 9, 10, and 11 are the block molds from which production molds are made.

This illustration gives only a slight idea of the complexities of mold making and of the necessity for working drawings and blue-prints,

particularly in those organizations lacking experience in elaborate mold work.

Earthenware Bowls

Figure 12 gives reproductions of sketches for earthenware bowls to be executed in underglaze decalcomania, modeled surfaces, and light colored glazes. These sketches are not intended as finished drawings. They are simply notes or ideas to be used for conference purposes and for further development.

Dinnerware Plates

In a previous paper[1] on shape construction, I suggested some possibilities in connection with dinnerware shapes and I made illustrations showing the mechanical construction of plates. A close study of the construction of every type of ceramic ware would undoubtedly result in a greater efficiency in production and in eliminating many losses which are entirely due to faulty construction.

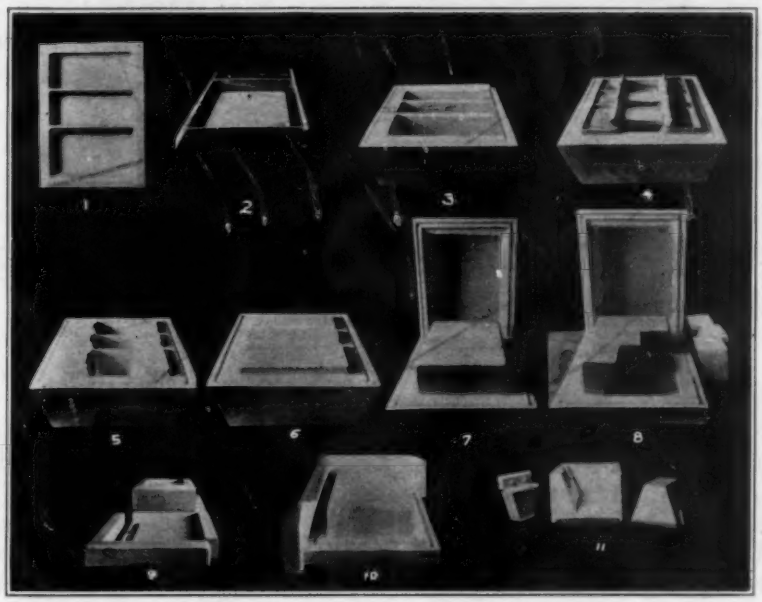

FIG. 11.

The Art Engineer and the Craftsman

A sharp distinction should be recognized between the art engineer whom I have in mind and the ceramic craftsman interested in small scale production. There is a wide difference in mental attitude between the two which almost inevitably makes the one type absolutely un-

[1] *Bull. Amer. Ceram. Soc.*, **2**, 64 (1923).

suited to the work of the other. The ceramic craftsman interested in the production of individual wares is controlled almost, if not entirely, by his personal preferences. His wares are expressions of his own individual and creative faculty to the exclusion of the tastes and preferences of any outside source. He is successful in proportion to the extent to which his creations meet with the approval of a small but widely scattered purchasing public. In other words, he creates and produces only those things which satisfy his creative instinct. This is supposed to be the spirit of the true artist and incidentally it is the spirit and faculty which is most harmful to the creative artist in a large industrial plant.

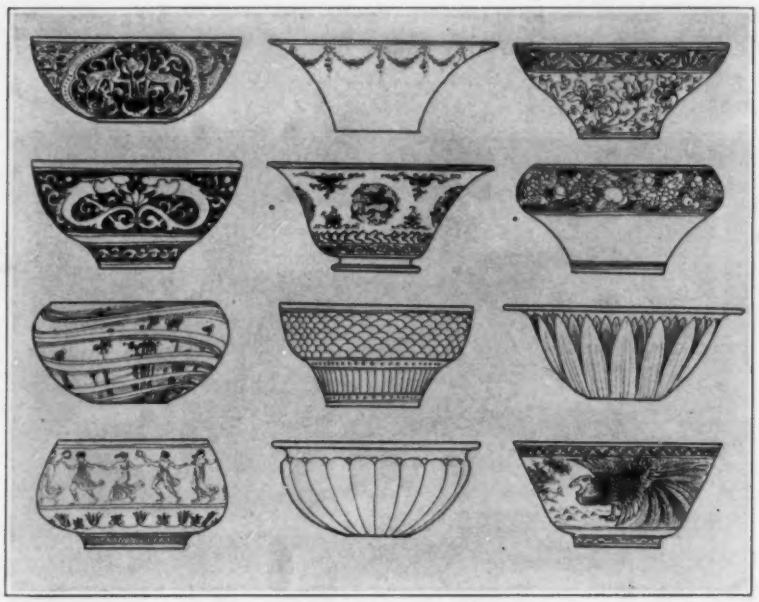

FIG. 12.

The art engineer or art director in a large ceramic organization may have strong personal preferences, but these must be entirely subordinate to market requirements without in any way affecting the quality of his work as far as technique and faithful artistic interpretation are concerned.

The ceramic art engineer is not an individualist; he is a craftsman with a wide knowledge of historical and modern ornament. He is also a close student of the purchasing public. He sees this public not as a single massed group, but as many different classes possessing different tastes, and with what is still more important, different potential purchasing possibilities. Stores of the Woolworth type, the large

department stores, specialty shops, and art stores are patronized by quite different classes of purchasers.

These tastes and preferences can be fairly accurately estimated and classified provided there is some serious attempt to study the various social groups, which altogether form what is known as the great American public. The following classification will certainly suggest different sales possibilities to the manufacturer and designer:

1. Foreign population having a primitive taste for color and decoration (30%).
2. The American working class, public school education, little knowledge of art and unconsciously accepting latest commercial offerings (40%).
3. High school and university public, average trade and professional classes, some superficial acquaintance with decorative style and a decided preference for a foreign product in contradiction to their sincere conviction that the United States is the greatest country in the world (20%).
4. College and cultured classes who are more or less familiar with the better types of commercial and art products, and who exercise what is currently accepted as being in good taste (5%).
5. Wealthy classes exercising a selection ranging anywhere from lavish and overcrowded decoration to the more conservative but equally expensive special products. (5%).

The creation of decorative wares which would be acceptable to any one of these groups is not a complicated problem. The present difficulty lies in the fact that most manufacturers and ceramic directors do not appeal directly to the tastes of a particular class. The purchasing public is considered as an uncertain quantity and the new decoration is more or less a gamble.

In the final analysis, commercial glass and china utilitarian articles are not purchased primarily as works of art, any more than wall paper or dining room furniture are purchased primarily for their aesthetic appeal. Glass and crockery are acquired because they are household essentials and their chief sales appeal depends on their fitness and appropriateness in relation to the remainder of the household effects. The various crockery articles must be of practical service. If a pitcher is easily filled, easily cleaned, if it pours well, has a well-balanced handle, and stands firmly on the table, it is a well-designed and incidentally a beautiful pitcher irrespective of its shape or decoration. In fact as far as the latter is concerned, the most wild-eyed artistic crank in the country could not spoil the beauty of form of such a shape.

American Encaustic Tiling Co.
Zanesville, Ohio

THE FROSTING OF GLASS BY MIXTURES CONTAINING HYDROFLUORIC ACID AND ALKALI FLUORIDES[1]

By C. D. Spencer and L. Ott

ABSTRACT

In this paper a number of experiments are described confirming the protection theory of acid frosting. A description is given also of an etching cell by means of which it is possible to observe, through a microscope, the initial stages and the progress of events during the acid etching of glass surfaces. A theory of the fortification or strengthening of abraded and acid-etched surfaces is proposed and illustrated.

I. The Matt Etching of Glass Surfaces

During the course of a research on the matt etching of glass it became apparent to us that there is a dearth of information on the chemistry and the physics of the reactions which occur during the acid frosting of glasses.[2] When a smooth, transparent surface of glass is treated with a solution containing hydrofluoric acid and an alkali fluoride, and the water soluble products of the reactions removed by washing, the glass surface is roughened or frosted. The formerly transparent surface is rendered translucent, and to the unaided eye an acid-frosted and a sand-blasted surface have much the same appearance. A low power microscope will serve to distinguish between these two surfaces and to emphasize the characteristic features of the acid-etched surface. Whereas the sand-blasted surface is typically irregular in structure the acid-frosted surface is covered by a tessellated pattern closely approaching regularity. It is the purpose of this paper to discuss the theory of the formation of matt-etched surfaces in general and to record some observations on the physical properties of these surfaces.

All glasses are soluble in hydrofluoric acid. This acid and its salts form the basis for etching or frosting mixtures. For the bright etching or acid polishing of cut glass concentrated hydrofluoric acid is used in combination with concentrated sulphuric acid. An aqueous solution of the acid, to which an alkali fluoride has been added, produces an entirely different effect. The presence of alkali fluorides in the etching mixtures results in a matt etching or frosting of the surface. The experiments described in this paper were carried out with frosting mixtures containing hydrofluoric acid in combination with sodium, potassium, and ammonium fluorides in varying proportions.

The opacity and the diffusion of etched surfaces is a function of the concentrations of the acid and the salts, and of the time of exposure and the temperature at which the reactions occur. Besides the acid

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., February, 1927. (Glass Division.)

[2] See E. W. Tillotson, Jr., "On the Relation between the Physical Properties and Chemical Composition of Glass. VII. Etch Figures", *Ind. Eng. Chem.*, 9 [10], 937 (1917).

and the fluoride salts frosting mixtures usually contain some form of sludge which acts as a filler or sponge. The sludge may be either an active or an inactive ingredient. The character of the resulting etch can be changed to some extent by the addition to the frosting mixture of some inactive salt such as ammonium sulphate, ammonium chloride, or ammonium oxalate.

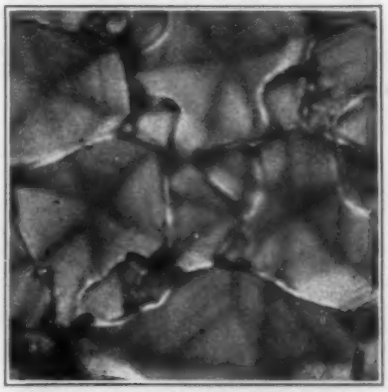

FIG. 1.

The attempt will be made in this paper to explain in some detail the protection theory of matt etching. But before considering the theory of acid frosting some of the facts to be coördinated will be presented.

Figure 1 is a photomicrograph of an acid-frosted surface of ordinary soda-lime glass at a magnification of 1100×. After etching the surface has been treated with hot water. A crystal-like pattern approaching regularity will be observed. It is easy to show, by means of india ink, that these crystalline appearing arears are elevations just as they appear to be in the photomicrographs.

Figure 2 is a photomicrograph of the same area observed in Fig. 1 after treatment with india ink. The ink has filled in the depressions leaving the elevations in relief. These crystalline appearing areas are very minute; the width at the base of the largest of them is between 10 and 15μ, and the height from the bottom of the deepest crevice to the top of the highest peak is between 4 and 8μ.

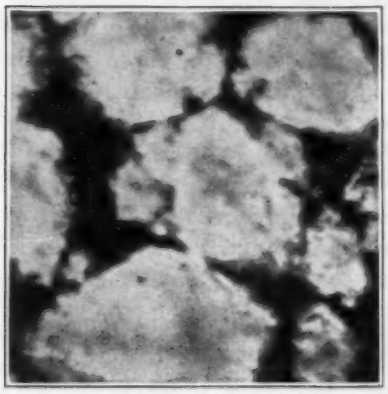

FIG. 2.

Referring again to Fig. 1, the apparent ruggedness of the plan view of the acid-frosted surface is deceiving because in reality the surface is but slightly roughened by frosting. A section through an acid-frosted surface is shown in Fig. 3. The magnification is 1100× and although the hill-and-hollow structure is evident it is difficult to represent the asperities in their true proportions.

The presence of these crystal-like areas on an acid-frosted glass surface can be explained by three very different theories. The first

theory assumes that glass has a cryptocrystalline structure and that the etching reaction depends on the same principle utilized in developing the crystal structure of metals. In support of such a theory the recent work of C. J. Smithells[1] on crystals in a lead glass could be quoted, but there is very little evidence on which to build a theory of the crystalline structure of the true silicate glasses.

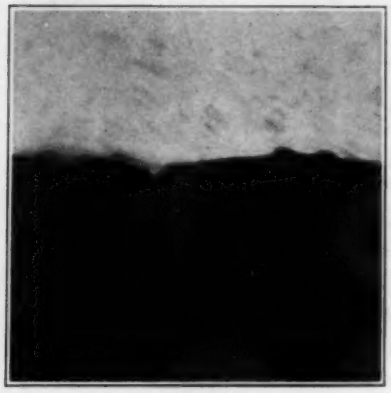

FIG. 3.

According to the second theory matt etching results from the deposition of a crystalline or amorphous precipitate on the glass surface during the frosting action. This theory was proposed as long ago as 1886 by F. Reinitzer[2] and references to it will be found even in the current literature on the subject. But it is not difficult to disprove this theory and to show that nothing but amorphous glass remains on the frosted surface. In the first instance there is no evidence of double refraction in the crystalline appearing areas and, even more to the point the surface structure of acid-frosted glass is unchanged by treatment with any reagent which does not itself affect glass.

The third or protection theory postulates that these crystalline-appearing areas consist of amorphous glass. During the acid frosting of a glass surface crystals of silicofluorides are formed and those crystals that form in contact with the glass surface protect the glass areas immediately beneath them from further attack. This theory will be amplified in the following paragraphs.

II. A Study of the Reactions Occurring during the Acid Frosting of Glass Surfaces. The Use of an Etching Cell and a Microscope to Observe the Initial Stage of the Frosting Reaction

In order to observe the initial stage of the etching reaction a simple cell was constructed of brass. The cell was about three inches in diameter and $\frac{3}{4}$ inch thick, formed of a section of a brass tube. One face of the cell was closed with a window of celluloid and the other consisted of a screw cap with a $\frac{1}{2}$-inch hole in the center. The glass

[1] C. J. Smithells, *Jour. Soc. Glass Tech.*, **10**, 145 (1926).

[2] F. Reinitzer, *Dingl. Polyt. Jour.*, **262**, 322–329 (1886) or *Jour. Soc. Chem. Ind.*, **5**, 669–70 (1886).

specimen to be etched was cemented to the inside surface of the cap, covering the hole in the center. Figure 4 shows the position of the cell when in use. The microscope was focused on the inside surface of the specimen of glass. The etching solution to be used was contained in the lead dish above the hard rubber funnel as shown in the figure. The funnel served to filter out any solid material present in the etching solution. When in use the cell was filled with water at a certain temperature and etching solution was added to the cell until the desired concentration was obtained. The progress of the frosting was observed through the microscope using 10× objective and 12.5× eyepiece.

FIG. 4.

The initial stage of the frosting reaction, under the conditions outlined above was the formation of a finely-divided precipitate at the interface between the glass and the solution. This precipitate was so finely divided that even at a magnification of 125× it was difficult to observe any evidence of crystallization. The precipitate was probably crystalline because after the lapse of a very short time small crystals made their appearance in the solution contiguous to the glass surface. These crystals could be observed to fall slowly through the liquid and at this stage of the reaction the whole glass surface seemed to be going into solution. Before long crystals were observed forming in contact with the glass surface itself. These crystals expanded laterally, and the more rapidly expanding areas very quickly established contact with their neighbors and interfered with the symmetrical development of the crystals. All of the glasses that we have examined behaved in this manner. We have experimented with dense lead glasses, ordinary soda-lime glasses, and heat-resisting borosilicate glasses.

On the basis of these observations we can explain the fact to be noted on all acid-frosted surfaces, that the crystalline appearing areas are prismatic or more properly speaking pyramidal in form. These areas appear as if they were built up or deposited on a plane surface. This effect can be seen to be the result of a concomitant solution of the glass surface and the growth of crystals of silicofluorides

on the surface of the glass. As the crystals grow and expand in area the glass immediately beneath them is protected from further attack. Tabular crystals, such as ammonium silicofluoride tend to develop in pyramidal form; prismatic crystals, such as sodium silicofluorides develop either in pyramidal form or as thin prismatic shells surrounding an amorphous glass core. Figure 5 is a photomicrograph at 250× of the development of a single crystal of ammonium silicofluoride on the surface of ordinary soda-lime glass. At *A*, the glass surface can be seen covered by the crystal and at *B*, the crystal has been removed by solution in water. Consider the sequence of events which occur after a crystal nucleus of the silicofluoride has formed in contact with the glass. During the entire period of growth of the crystal the unprotected surface of the glass at any instant has been exposed to the solvent action of the etching solution. Because of this solvent action successive increments in area of the crystal are formed on planes parallel to the original surface of the glass but at increasingly greater distance from it. In this manner a pyramidal boss or protuberance orginates during the crystallization of the silicofluorides on the glass surface. The forces of crystallization undoubtedly play the major rôle in the development of the surface structure of acid-frosted glasses. Surface tension also exerts its influence in the development of the fine structure of the etched surface, and this is particularly notable on etched surfaces that have been further treated, after etching, with hydrofluoric acid solutions.

III. The Resistance to Rupture of Frosted Glass Hollow-ware as a Function of the Condition of Surface and the System of Stresses Applied

It is common knowledge in the glass industry that hollow-ware sand-blasted or acid-etched on the inside is very fragile and subject to breakage. The exterior surface of a piece of hollow-ware may be frosted without impairing the mechanical strength of the article but as a usual thing excessive breakage results when the interior surface is roughened. A mechanical explanation for this phenomenon may be suggested as follows. Roughening the surface by sand-blast develops a cone flaw-complex with many fine fissures covering the entire surface.[1] From analogies with the mechanical properties of metals we can predict that these flaws of small radius of curvature will increase

[1] A very interesting article on this subject has been published by F. W. Preston, "The Structure of Abraded Glass Surfaces," *Trans. Opt. Soc.*, **23**, 141–64 (1921–22).

the maximum stress many times. A. A. Griffith[1] has shown that in the case of an iron wire spirally scratched with Carborundum cloth the presence of scratches 2.5μ deep increased the maximum stress three or four times. In the case of the sand-blasted surface it is possible to estimate an upper limit to the magnitude of the radius of curvature near the ends of the flaws in the surface. By observations of the interference colors near the ends of fine cracks in glass plates it can be shown that the radius of curvature is of the order of 50$\mu\mu$. These observations furnish ample evidence to support the thesis that under certain systems of stresses sand-blasted glass hollow-ware would be many times less resistant to mechanical shock than hollow-ware with polished surfaces. Any system of stresses resulting in an extention or an increase in area of the sand-blasted surface will promote rupture at relatively low values of the applied stresses. To complete the analogy between the mechanical weakness of acid-frosted and abraded surfaces it is only necessary to show that there are present on the surface of acid-frosted glass, areas of radius of curvature of the order of 2.5μ or less. This can be seen to be a logical assumption, *e.g.*, any two pyramidal areas as illustrated in Fig. 1. From the data given in the first part of this paper these pyramids cover an area of about 10$\mu\times$10μ at the base and they are 5μ in altitude. If these pyramids intersect in the plane of their bases then along the line of intersections the radius of curvature of the depression is certainly less than 5μ

A *B*

FIG. 5.

It is possible to explain by means of the theory outlined above why a piece of hollow-ware frosted on the outside surface is mechanically as strong as before treatment, and likewise why excessive fragility is brought about by frosting the inside surface. Consider the distribution of the stresses to which a thin, spherical shell is subjected in ordinary handling. Impacts or shocks on the exterior surface cause tension stresses in the layers of glass adjacent to the interior surface. Flaws of small radius of curvature will tend to extend under tension stresses but will heal under compression stresses. As a corollary to this theory we can make two predictions.

[1] *Phil. Trans. Roy. Soc. of London*, *A*, **22**, 163–98 (1920).

(*a*) Outside frosted hollow-ware should rupture easily when exposed to impacts against the inside surface.

(*b*) Inside frosted hollow-ware should be relatively stronger to impacts against the inside surface than to impacts against the outside surface.

Our experiments have demonstrated the truth of both of these predictions. The resistance to shock or impact of a large number of thin-blown pieces of hollow-ware was tested in the following manner. A small ball was dropped through a measured distance, impinging upon the surface under test. The resistance to shock is a function of the distance through which the ball falls before making contact with the surface. When tested in this way outside frosted hollow-ware is apparently strong to impacts against the exterior surface, but it is very fragile when exposed to impacts against the inside surface. On the contrary, inside frosted hollow-ware that will shatter at a mere tap on the exterior surface develops quite a remarkable resistance to shock when impacts are directed against the frosted surface.

IV. A Theory of the Fortification of Abraded and Acid-Etched Surfaces

In the preceding parts of this paper we have outlined a theory to explain the mechanical weakness of inside frosted hollow-ware. This theory is based on the fact that the frosting of glass by abrasion or by acid etching produces on the surface fissures of very small radius of curvature. If this is true it should be possible to fortify or to restore the mechanical strength of inside frosted hollow-ware by treating the frosted surface in such a manner that the radius of curvature of these minute fissures is increased. The glazer utilizes this principle to prevent the advancement of a crack in a plate-glass window. A small hole is drilled through the plate of glass at the vertex of the crack. The function of this hole is to increase the radius of curvature at the end of the crack. In this way the stresses caused by temperature gradients and distortion of the plate are distributed over a large area and so reduced in intensity that they do not exceed the modulus of rupture of the glass. If these fissures of minute radius of curvature are responsible for the mechanical weakness of inside frosted hollow-ware then any reagent that will dissolve glass should fortify a frosted surface. The radius of curvature of these minute fissures will be increased during the solution of the glass. Whenever the minimum radius of curvature of all fissures on the frosted surface exceeds a certain magnitude the mechanical strength of the frosted article should be restored to very nearly its original value. As a test of this theory frosted surfaces have been fortified by aqueous solutions of such diverse

chemical compounds as hydrofluoric acid and sodium carbonate. Even boiling water, which has a solvent action for soda-lime glass, can fortify a frosted surface to a measurable extent.

Figure 6 is a photomicrograph at a magnification of 1100× of an acid-frosted surface after treatment for a short interval of time with an acid fortifying solution. The attack of the fortifying solution has been confined to the minute fissures between the protuberances. This figure illustrates the rounding out or the increase in the radius of curvature of the fissures. It will be noted that each fissure on the frosted surface has been transformed into a connected series of hemispherical depressions. In this way each protuberance on the original frosted surface becomes surrounded by a chain of these hemispherical depressions. As the action of the fortifying solution is prolonged these depressions increase in area and at the final stage of the reaction the crystal-like bosses disappear. The appearance of a fully fortified surface is shown in Fig. 7. In the upper right quadrant the remains of two protuberances can be distinguished but even these vestiges would be removed by continued fortification. In particular we would emphasize the statement that fortification depends on the solution of the glass.

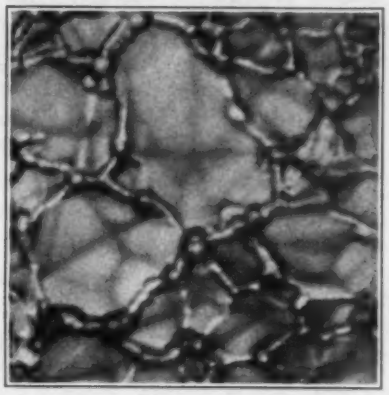

FIG. 6.

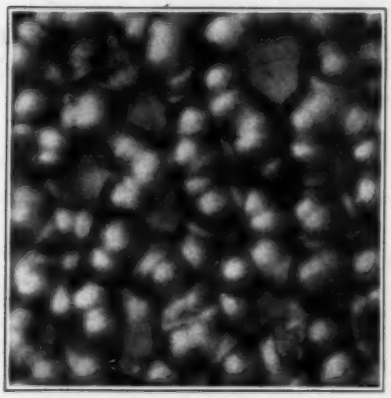

FIG. 7.

The chemical composition of a number of frosting and fortifying mixtures has been given by M. Pipkin.[1] A description is given also of an impact device for testing the mechanical strength of frosted hollow-ware. The data obtained by means of this ivory ball tester illustrate the unusual fragility of inside frosted lamp bulbs and the remarkable increase in strength of the frosted bulb that has been treated with a fortifying mixture.

[1] "The Inside Frosting of Incandescent Lamps," *Ind. Eng. Chem.*, **18**, 774–76 (1926).

It has been the aim of this paper to correlate various observations on the matt etching of glass and to confirm the protection theory of acid frosting. The forces of crystallization and surface tension have been shown to be sufficient to account for the surface structure of acid-frosted glasses. A theory of the mechanical weakness of frosted hollow-ware has been based on the known physical properties of fissures of small radius of curvature. It has been suggested that the fortifying action of different solvents for glass depends on the enlargment of these minute fissures. The theory of the etching of glass is essentially chemical in nature but throughout this study attention has been concentrated on the physics involved in the development of the peculiar structure of acid-frosted glass surfaces.

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INCANDESCENT LAMP DEPARTMENT
GENERAL ELECTRIC COMPANY
CLEVELAND, OHIO

BUREAU OF STANDARDS INVESTIGATION OF FELDSPAR—SECOND PROGRESS REPORT[1]

By R. F. Geller

ABSTRACT

The history and purpose of the investigation are outlined and detailed reports are made on (1) the results of air elutriation and coöperative sieve and chemical analyses of the nineteen feldspars being studied, (2) coöperative determinations of softening point, and (3) true specific gravity. The paper also includes a report on tests of mechanical strength, light transmission, porosity, volume shrinkage during firing, and thermal expansion of whiteware specimens in which the feldspars being studied were the only variable component.

Introduction

The comprehensive study of all raw materials entering into the manufacture of whiteware bodies, started by the Bureau of Standards in 1922 and of which this investigation of feldspar is a part, has been outlined and described in the literature.[2] The immediate purpose of this investigation is to determine the qualities of the commercial raw materials and the relation of these qualities to the properties of the product. The ultimate purpose is the development of better products through a better understanding of the fundamental qualities of the raw materials and of the reactions involved in the manufacture of whiteware bodies. The First Progress Report on Feldspar was published in 1925;[3] it contained a brief analysis of the data on grain size, chemical composition, and softening points (in terms of pyrometric cones) then available and compared these determined qualities of the nineteen commercial feldspars investigated with the requirements of the Tentative Feldspar Specification proposed by the Whiteware Division of this Society.[4]

As stated in previous reports,[5] the feldspar investigation was started with the coöperation of a Special Committee on Feldspar of the Whiteware Division and the samples of feldspar were obtained for the Bureau (with two exceptions) from the users by R. V. Knowles.

Scope

The investigation, as originally outlined, is to include the following determinations:

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[1] Published by permission of the Director, U. S. Bureau of Standards, Department of Commerce. Received March 11, 1927.

[2] *The Ceramist*, September, p. 375 (1924).

[3] *The Ceramist*, September, p. 708 (1925).

[4] *Bull. Amer. Ceram. Soc.*, **2** [6], 163–65 (1923).

[5] *The Ceramist, loc. cit.*

Part I.—Determinations to be made on each feldspar

A. Fineness of grind, to be determined both with sieves and by air elutriation[1]

B. Composition, to be determined by chemical means

C. Softening range

D. Softening point expressed in terms of cones

E. Fusion point expressed in temperature

F. True specific gravity, both as received and after partial and complete fusion

G. Thermal expansion, after partial and complete fusion

H. Relative viscosity while molten

I. Petrographic analysis

Part II.—Determinations to be made on bodies in which the feldspar used is the only composition variable:

A. Firing behavior and maturing range, as evidence by porosity and volume shrinkage

B. Color and translucency

C. Mechanical strength

D. Composition, as determined by petrographic means

E. Effect of feldspars used in relative "glaze fit"

F. Thermal expansion

Materials Used

The feldspars being used in this study are given in Table I (*a*) together with the name of the producer and the location of the mine. For obvious reasons they are not given in the same order as in the other tables. For the significance of the key numbers see note to Table II.

TABLE I (*a*)
CLAYS AND FELDSPARS USED IN INVESTIGATION

Trade Name	From	Produced by
Minpro No. 1	Mitchell Co., N. C.	Tennessee Mineral Products Co.
"42"	" " "	Golding and Sons
Madoc	Hastings, Ont.	Pennsylvania Pulverizing Co.
Canadian No. 1	Near Quebec	R. L. Cawood Co.
"45"	Cecil Co., Md.	Golding and Sons
Maryland	Carroll Co., Md.	Seaboard Feldspar Co.
Keene	Cheshire Co., N. H.	Golding-Keene Co.
—	St. Lawrence Co., N. Y.	Green Hill Mining Co.
R. Sant	Mitchell Co., N. C.	Erwin Feldspar Co.
"54"	Cecil Co., Md., and Mitchell Co., N. C.	Golding and Sons
Derry	Buckingham, Quebec	Dominion Feldspar Corporation
"27"	Georgetown, Maine	Golding and Sons
—	Lincoln Co., Maine	Cummins Feldspar Co.
Virginia	Bedford Co., Va.	Seaboard Feldspar Co.
Glaze	Gildersleeve, Conn.	Eureka Flint & Spar Co.
No. 1	Mitchell Co., N. C.	Clinchfield Products Co.
Canadian No. 1	Balderson, Ont.	Rock Products Co.
Puritan	Cheshire Co., N. H.	Golding-Keene Co.
Maine	Topsham and Auburn, Maine	Maine Feldspar Co.

The domestic ball clay used is known as Tennessee No. 5, obtained in 1926 from the Chas. M. Franzheim Company. The Florida kaolin

[1] J. C. Pearson and W. H. Sligh, "An Air Analyzer for Determining the Fineness of Cement," Bur. of Stand., *Tech. Paper*, No. 48.

was obtained in 1923 from the Florida China Clay Company and the North Carolina kaolin in 1926 from the Chas. M. Franzheim Company. The English ball clay (Dorset) and china clay were furnished by the Paper Makers Importing Company in 1925 and the flint by the National Silica Company, also in 1925. The whiting (English potter's) was obtained in 1923 from Roessler & Hasslacher Chemical Company. (See Table I(*b*)).

TABLE I (*b*)
CHEMICAL COMPOSITIONS OF CLAYS (in per cent)

	English ball clay (Dorset) 1	Ball clay (Tenn. No. 5) 2	Florida kaolin 3	North Carolina kaolin 4	English china clay 5
Ignition loss	17.2	12.4	15.3	15.9	12.6
SiO_2	44.4	56.7	44.6	46.1	46.3
Al_2O_3	33.6	25.8	38.2	34.9	38.4
Fe_2O_3	1.28	1.1	0.79	0.80	0.86
TiO_2	0.8	1.6	0.8	0.1	0.2
CaO	0.3	0.2	0.3	0.2	0.1
MgO	0.5	0.5	0.3	0.1	0.5

LINEAR THERMAL EXPANSIONS OF CLAYS (in per cent)

1		2		3		4		5	
°C	Exp.	°C	Exp.	°C	Exp.	°C	Exp.	°C	Exp.
109	.037	109	.053	118	.095	134	.037	110	.033
212	.083	212	.133	202	.199	205	.070	198	.080
303	.126	303	.188	303	.260	289	.114	281	.119
393	.172	393	.243	383	.307	386	.161	385	.165
476	.210	476	.297	479	.371	477	.196	465	.203
526	.234	526	.338	537	.406	523	.219	524	.226
589	.268	589	.405	591	.445	588	.267	583	.257
701	.334	701	.467	696	.506	694	.323	685	.311
800	.399	800	.513	789	.564	792	.373	784	.366
881	.451	881	.545	892	.612	887	.401	897	.415
993	.511	993	.592	998	.664	995	.470	998	.464

I. Tests of Individual Feldspars

A. Sieve Analysis

The sieve analyses were made at the Bureau and by four coöperating industrial laboratories.[1] The following methods were followed:

Lab. No. 1 "Standard screen scale laboratory sieves Nos. 100, 140, 200, and 270 were used and the analyses made according to the method given in the recommended feldspar specifications of the AMERICAN CERAMIC SOCIETY.[2]"

Lab. No. 2 (Bureau of Standards, Ceramic Division): Standard scale calibrated sieves Nos. 100, 200, 270, and 325 were used.

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[1] General Electric Co. (Schenectady, N. Y.); AC Spark Plug Co. (Flint, Mich.); Western Electric Co. (Hawthorne Sta., Chicago); and the Onondaga Pottery Co. (Syracuse, N. Y.).

[2] *Jour. Amer. Ceram. Soc.*, **6** [6], 165 (1923).

Lab. No	Per cent Residue on Sieve No. 100	200	325	Total on sieve 325
Feldspar No. 1 (7)				
1	0.2	0.9		
2A	0.2	1.2	6.5	7.9
B	0.2	1.0	3.9	5.1
3	0.1	3.7	6.4	10.3
4	0.4	1.7	6.7	8.8
5	1.3	0.5		
Av.	0.4	1.6	6.5	9.0
Per cent greater than			0.04 mm	20.5
" " " "			0.02 mm	38.2
Feldspar No. 2 (18)				
2A	0.1	2.1	8.3	10.5
B	0.1	1.9	5.3	7.3
Per cent greater than			0.04 mm	27.1
" " " "			0.02 mm	47.9
Feldspar No. 3 (11)				
1	0.2	0.3		
2A	0.2	2.1	7.1	9.4
B	0.2	1.9	5.4	7.5
3	0.2	3.0	6.2	9.4
4	0.4	0.7	7.5	9.5
5	0.4	0.8		
Av.	0.3	1.4	6.9	9.4
Per cent greater than			0.04 mm	22.0
" " " "			0.02 mm	45.1
Feldspar No. 4 (5)				
1	0.8	8.2		
2A	0.8	7.2	13.1	21.1
B	0.7	6.6	8.3	15.6
3	1.0	9.0	9.9	19.9
4	1.2	7.6	12.3	21.1
5	1.9	5.0	18.6	25.5
Av.	1.1	7.4	13.5	21.9
Per cent greater than			0.04 mm	32.7
" " " "			0.02 mm	53.6
Feldspar No. 5 (4)				
1	0.0	0.9		
2A	0.0	0.9	4.4	5.3
B	0.0 (0.0)	0.7 (1.2)	2.7 (2.6)	3.1
3	0.0	2.1	4.9	7.0
4	0.1	0.7	3.5	4.3
5	0.5	1.0	11.5	13.0
Av.	0.1	1.1	6.1	7.4
Per cent greater than			0.04 mm	18.8
" " " "			0.02 mm	38.3
Feldspar No. 6 (8)				
1	0.7	2.2		
2A	0.5	4.5	8.6	13.6
B	0.5	4.2	6.0	10.7
3	0.5	7.3	8.6	17.4
4	2.5	5.0	7.1	14.6
5	0.4	1.1		
Av.	0.9	4.0	8.1	15.2
Per cent greater than			0.04 mm	23.1
" " " "			0.02 mm	39.1

Lab. No.	Per cent Residue 100	200
Feldspar N		
1	0.3	0.5
2A	0.3	1.7
B	0.3	1.5
3	0.3	2.1
4	0.4	1.9
5	1.5	0.5
Av.	0.5	1.3
Per cent greater tha		
" " " "		
Feldspar N		
1	0.1	0.5
2A	0.1	2.5
B	0.1	1.9
Av.	0.1	1.4
Per cent greater tha		
" " " "		
Feldspar N		
2A	0.1	1.4
B	0.1	1.2
Per cent greater tha		
" " " "		
Feldspar N		
1	0.2	4.0
2A	0.2	3.6
B	0.2 (0.2)	3.3 (4.
3	0.2	5.1
4	0.4	3.9
5	0.4	2.9
Av.	0.3	3.9
Per cent greater tha		
" " " "		
Feldspar N		
1	0.1	1.2
2A	0.1	1.8
B	0.1	1.6
3	0.1	2.2
4	0.1	2.4
5	0.2	0.5
Av.	0.1	1.6
Per cent greater tha		
" " " "		
Feldspar N		
1	0.0	0.3
2A	0.0	0.2
B	0.0 (0.0)	0.1 (0.
3	0.0	0.1
4	0.0	0.3
5	0.2	0.7
Av.	0.0	0.3
Per cent greater tha		
" " " "		
Feldspar N		
1	0.1	1.2
2A	0.1	2.2
B	0.1	1.9
3	0.1	2.5
4	0.1	3.0
5	0.3	0.4
Av.	0.1	1.8
Per cent greater tha		
" " " "		

NOTE: The results reported for Lab. No. 3 are the average of two determinations. The results under A for Lab. 2 (Bureau of Standards) are equivalent to results obtained by wet sieving alone (see text). The results given under B Lab. No. 2 were obtained by combined wet and dry sieving (see text). The results given parenthetically under B Lab. No. 2 in the case of feldspars Nos. 5, 10, 12 and 19 are check determinations by a second investigator at the Bureau.

The feldspars are arra
creasing K_2O content and
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the feldspars were submitt
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of Commercial Feldspars,"

TABLE II

Lab. No.	Per cent Residue on Sieve No. 100	200	325	Total on sieve 325
Feldspar No. 7 (16)				
		0.5		
		1.7	7.0	9.0
		1.5	4.1	5.9
		2.1	5.8	8.2
		1.9	8.6	10.9
		0.5		
		1.3	7.1	9.4
	Per cent greater than		0.04 mm	23.5
	" "		0.02 mm	40.7
Feldspar No. 8 (17)				
		0.5		
		2.5	11.4	14.0
		1.9	6.2	8.2
		1.4	11.4	14.0
	Per cent greater than		0.04 mm	27.9
	" "		0.02 mm	52.1
Feldspar No. 9 (19)				
		1.4	6.0	7.5
		1.2	3.9	5.2
	Per cent greater than		0.04 mm	23.3
	" "		0.02 mm	40.1
Feldspar No. 10 (1)				
		4.0		
		3.6	9.3	13.1
.2)	3.3 (4.7)		6.7 (6.1)	10.2
		5.1	9.5	15.0
		3.9	10.8	15.1
		2.9	22.3	25.6
		3.9	13.0	17.2
	Per cent greater than		0.04 mm	27.6
	" "		0.02 mm	48.8
Feldspar No. 11 (14)				
		1.2		
		1.8	7.8	9.7
		1.6	5.0	6.7
		2.2	6.2	8.5
		2.4	9.5	12.0
		0.5		
		1.6	7.8	10.1
	Per cent greater than		0.04 mm	34.1
	" "		0.02 mm	48.3
Feldspar No. 12 (15)				
		0.3		
		0.2	2.2	2.4
.0)	0.1 (0.2)		0.9 (1.0)	1.0
		0.1	1.7	1.9
		0.3	4.9	5.2
		0.7		
		0.3	2.9	3.2
	Per cent greater than		0.04 mm	21.6
	" "		0.02 mm	47.9
Feldspar No. 13 (13)				
		1.2		
		2.2	8.9	11.2
		1.9	4.8	6.8
		2.5	7.4	10.0
		3.0	10.5	10.9
		0.4		
		1.8	8.9	10.7
	Per cent greater than		0.04 mm	25.3
	" "		0.02 mm	49.1
Feldspar No. 14 (10)				
1	1.7	0.7		
2A	2.1	1.9	6.6	10.6
B	2.1	1.8	4.0	7.9
3	2.2	2.6	5.5	10.3
4	2.3	2.2	7.2	11.7
5	2.1	1.1		
Av.	2.1	1.7	6.4	10.8
	Per cent greater than		0.04 mm	23.0
	" "		0.02 mm	41.9
Feldspar No. 15 (2)				
1	0.2	1.4		
2A	0.1	2.2	8.7	11.0
B	0.1	2.0	6.4	8.5
3	0.1	3.0	8.3	11.4
4	0.1	2.5	17.6	20.2
5	2.2	0.7	15.6	26.7
Av.	0.5	2.0	12.5	17.3
	Per cent greater than		0.04 mm	27.0
	" "		0.02 mm	54.6
Feldspar No. 16 (9)				
1	0.2	0.8		
2A	0.2	2.3	7.9	10.4
B	0.2	2.0	5.0	7.2
3	0.2	3.5	6.4	10.3
4	0.3	2.2	9.0	11.5
5	0.4	1.0		
Av.	0.3	2.0	7.8	10.7
	Per cent greater than		0.04 mm	23.1
	" "		0.02 mm	41.5
Feldspar No. 17 (6)				
1	0.2	2.0		
2A	0.1	1.8	4.6	6.2
B	0.1	1.8	3.8	5.7
3	0.1	3.7	6.0	9.8
4	0.3	1.9	6.0	8.2
5	1.4	1.0	11.4	13.8
Av.	0.4	2.1	7.0	9.5
	Per cent greater than		0.04 mm	17.0
	" "		0.02 mm	32.4
Feldspar No. 18 (12)				
1	0.1	2.1		
2A	0.1	3.8	11.3	15.2
B	0.1	3.5	6.6	10.2
3	0.1	4.6	9.2	14.0
4	0.2	4.7	10.3	15.2
5	0.4	1.6		
Av.	0.2	4.2	10.3	14.8
	Per cent greater than		0.04 mm	28.6
	" "		0.02 mm	46.6
Feldspar No. 19 (3)				
1	0.3	2.9		
2A	0.3	4.5	9.4	14.2
B	0.2 (0.1)	4.1 (5.5)	6.6 (6.0)	10.9
3	0.2	7.0	9.0	16.1
4	0.7	6.6	9.1	14.4
5	0.8	4.3	16.2	21.3
Av.	0.5	5.1	10.9	16.5
	Per cent greater than		0.04 mm	24.6
	" "		0.02 mm	42.7

rs are arranged in the order of in-
ontent and are numbered accord-
numbers given parenthetically are
riginally assigned to the feldspars
and are the numbers under which
ere submitted to coöperating labo-
o the numbers used by H. Insley in
he petrographic analyses of these
Quantitative Microscopic Analysis
Feldspars," *loc. cit.*

General Averages

	Per Cent
Residue on No. 100 sieve	0.4
" " " 200 "	2.4
" " " 325 "	8.5
Total on " 325 "	11.8
Per cent greater than 0.04 mm	24.8
" " " " 0.02 mm	44.7

A 100-gram sample was placed on the No. 325 sieve and washed gently without brush until the fines were removed. The sieves were then stacked and the residue transferred to the top sieve (No. 100) and the material washed on each sieve over the remainder of the stack, a soft brush being used to break down aggregates. The residues were then dried on the sieves and the regular method of dry sieving used after which both the final residue on each sieve, and the fines removed by the dry sieving, were weighed. The results given under A (Table II) are the sum of the final residues and the fines (equivalent to wet sieving alone) and the results given under B are those obtained by the combined wet and dry sieving. While the B method is advocated, the results are not considered in the averages since the method was not used by any of the coöperating laboratories.

Lab. No. 3: "100-gram samples are weighed out and washed through a No. 325 sieve to remove the very fine material. The residue on the sieve is then washed through the following series of sieves: 100-mesh, 120-mesh, 150-mesh, 200-mesh, 270-mesh, and 325-mesh. After thorough washing the residues are dried at 110°C and then weighed."

The results given in Table II are the averages of two determinations.

Lab. No. 4: Sieves Nos. 100, 150, 200, 250, and 325 were used. The method used was described as follows: "Weigh out a sample of 250 grams, blunge for ten or fifteen minutes by means of a small motor-driven stirrer, then wash this slip through the several screens with the aid of a jet of water delivered through a rubber tube. In this way very little brush work is necessary."

Lab. No. 5: Tyler screens Nos. 100, 140, 200, 250, 300, and 325 were used. Method used was described as follows: "We followed as far as possible the method of testing as outlined in the pamphlet."[1] "However, we used a separate sample for each screen."

Although the determinations by the five laboratories were made on carefully prepared portions of the same samples it is realized that they are not directly comparable since different methods were followed, sieves of the same number were not used throughout and the calibration of the sieves used by the coöperating laboratories is not known. However, they do show the variation in results actually obtained on the same material by five laboratories, any one of which would probably consider its results as final in the case of a dispute. Sieves Nos. 100, 200, and 325 were used in practically every instance (Lab. No. 1 did not use sieve No. 325) and therefore the results were calculated to residues on these three sieves and are presented in Table II). It is

[1] *Jour. Amer. Ceram. Soc., loc. cit.*

interesting to note that the data as originally submitted by one laboratory were given to the nearest 0.001% and by two laboratories to the nearest 0.01%. It is probably true that one operator, using exactly the same method and the same sieves, can repeatedly check himself to within 0.1%, but it is quite evident from the data in Table II that a fineness requirement to even 0.5% would have little significance in a general specification. For convenience the range of variations is shown graphically in Fig. 1 (values obtained by B method, Lab. 2, not plotted).

The average residue on the No. 100 sieve (Fig. 1) varied from 0.0 to 2.1% (feldspars Nos. 12 and 14) and the final average was 0.4%. Only two samples (Nos. 4 and 14) showed a residue of over 1.0%. The maximum variation between laboratories, on individual samples, was 2.1% and the average variation for all the samples was 0.7%.

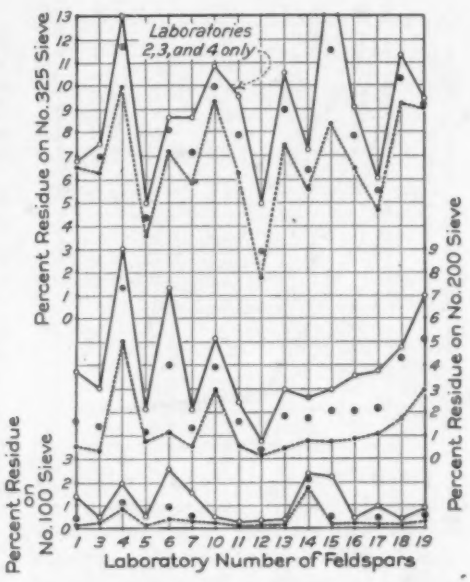
Laboratories 2,3,and 4 only
Percent Residue on No.325 Sieve
Percent Residue on No.200 Sieve
Percent Residue on No.100 Sieve
Laboratory Number of Feldspars
1 3 4 5 6 7 10 11 12 13 14 15 16 17 18 19

FIG. 1.—Values plotted to show variations in fineness determinations as obtained by five laboratories working independently but on portions of the same samples.

The average residue on the No. 200-sieve varied from 0.3 to 7.4% (feldspars Nos. 12 and 4) and the final average was 2.4%. A majority of the samples (12 out of 19) showed a residue of 2.0% or less. The maximum variation between laboratories, on individual samples, was 6.2% (feldspar No. 6), and the average variation for all the samples was 2.6%.

The average residue on the No. 325 sieve (averaged for Laboratories 2, 3, and 4 only, Fig. 1) varied from 2.9 to 11.7% (feldspars Nos. 12 and 4) and the final average for all the samples (Laboratories 2, 3, and 4 only) was 7.9%. The maximum variation between laboratories 2, 3, and 4, on individual samples, was 9.3% (feldspar No. 15) and the average variation for 16 samples (Fig. 1) was 2.4%. That the average variation for sieve No. 325 did not exceed that for sieve No. 200 (as could logically be expected) is due to the elimination of results from Laboratory No. 5 where, as previously noted, a method differing

radically from that of the others was used and which produced results generally varying most from the average.

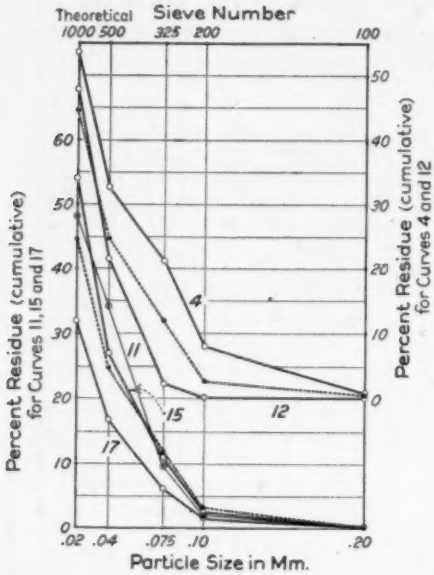

FIG. 2.—Curves showing the relation of extremes in fineness, as determined by air analysis, with extremes as determined with sieve No. 325.[2] Curves 15 and 17 are extremes as based on results of .02 mm separation. Curves 11 and 17 are extremes as based on results of .04 mm separation. Curves 4 and 12 are extremes as based on No. 325 sieve separation. Dotted line is average for *all* feldspars.

Pressler and Shearer[1] found a fairly constant relation between the 0.02 and 0.04 mm separations by air elutriation and the sieve tests of potter's flint, but this is not true of the feldspars examined. As shown in Fig. 2, the extremes of fineness according to residues on the No. 325 sieve (feldspars Nos. 12 and 4) do not correspond to the extremes according to either the 0.04 mm separation (feldspars Nos. 11 and 17) or the 0.02 mm separation (feldspars Nos. 15 and 17). Both the coarsest and the finest-ground samples (Fig. 2), by sieve No. 325 results (Nos. 4 and 12), are among the coarsest by the 0.02 mm separation and the general average (values connected by dotted line) practically coincides with the 0.02 and 0.04 mm separation values for feldspar No. 12. On the other hand, the finest feldspar by the 0.02 mm separation (feldspar No. 17) is below the general average for residues on the No. 325 sieve.

The nineteen samples can be divided into fairly well-defined groups according to fineness, as in Table III.

TABLE III

Total Residue on No. 325 sieve			0.02 mm separation		
Group	Residue	Samples	Group	Residue	Samples
A	3.2 to 9.5% (Av. 7.9)	1, 3, 5, 7, 9 and 12 and 17	a	32 to 43% (Av. 39.4)	1, 5, 6, 7, 9, 14 and 16, 17 and 19
B	10.0 to 15% (Av. 11.7)	2, 8, 11, 13 and 14, 16 and 18	b	45 to 50% (Av. 47.7)	2, 3, 10, 11 and 12, 13 and 18
C	15.0 to 22% (Av. 17.6)	4, 6, 10, 15 and 19	c	52 to 55% (Av. 53.4)	4, 8 and 15

[1] "The Properties of Potter's Flints and Their Effects in White-Ware Bodies." Bur. of Stand., *Tech. Paper*, No. 310, p. 295.

[2] See also "The Particle Size Distribution of Typical Feldspars and Flints," *Jour. Amer. Ceram. Soc.*, **10** [4], 264–67 (1927).

TABLE IV
CHEMICAL COMPOSITION

Feldspar No.	Lab.	Ignition loss	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	K_2O+Na_2O	Total alkalis	Total
1	1A	0.5	67.4	20.0	0.27	t	0.5	0.2	1.0	10.0	11.0		
	1B	0.5	68.2	19.2	0.39	0.0	0.7	0.3	1.3	10.0	11.3		
	2	0.6	67.7	19.6	0.18	0.0	0.5	0.2	0.9	10.0	10.9		
	Av.	0.5	67.8	19.6	0.28	0.0	0.6	0.2	1.1	10.0	Av. 11.1	11.9	100.1
2	1A	0.6	73.1	15.4	0.06	0.0	0.8	s.t.	4.5	5.6	10.1		
	1B	0.5	74.1	14.3	0.09	0.0	0.9	0.3	4.5	5.4	9.9		
	2	0.5	73.9	15.0	0.05	0.0	0.7	0.2	4.3	5.7	10.0		
	Av.	0.5	73.7	14.9	0.06	0.0	0.8	0.2	4.4	5.6	Av. 10.0	11.0	100.2
3	1A	0.6	67.4	19.4	0.16	s.t.	0.5	0.4	5.2	5.7	10.9	11.8	99.4
4	1A	0.8	70.9	17.5	0.12	s.t.	0.3	s.t.	6.4	3.9	10.3	10.6	99.9
5	1A	0.6	71.8	16.1	0.15	t	0.7	t	7.0	3.5	10.5		
	1B	0.6	72.2	14.6	0.18	0.0	0.8	0.4	7.8	3.4	11.2		
	2	0.7	72.1	15.1	0.08	0.0	0.6	0.4	7.6	3.4	11.0		
	Av.	0.6	72.0	15.3	0.11	0.0	0.7	0.3	7.5	3.4	Av. 10.9	11.9	99.9
6	1A	0.6	70.6	16.4	0.12	0.0	0.6	0.3	7.5	3.3	10.8	11.7	99.4
7	1A	0.5	73.2	15.8	0.19	s.t.	0.5	s.t.	7.6	2.8	10.4	10.9	100.6
8	1A	0.7	67.8	18.4	0.37	s.t.	0.9	t	8.4	3.6	12.0	12.9	100.2
9	1A	0.4	71.1	16.1	0.09	s.t.	0.5	s.t.	9.0	3.0	12.0	12.5	100.2
10	1A	0.7	67.6	18.8	0.04	0.0	0.8	s.t.	9.1	3.3	12.4		
	1B	0.6	68.5	17.9	0.23	0.0	0.9	0.1	9.4	3.2	12.6		
	2	0.6	67.8	18.0	0.06	0.0	0.8	0.1	9.0	3.4	12.4		
	3	0.5	67.8	17.9	0.20	0.0	0.9	0.0	9.2	3.3	12.5		
	Av.	0.6	67.9	18.2	0.13	0.0	0.9	0.05	9.2	3.3	Av. 12.5	13.4	100.2
11	1A	0.3	68.7	17.9	0.16	0.0	0.5	s.t.	9.1	3.4	12.5	13.0	100.1
12	1A	0.2	68.8	18.2	0.10	0.0	0.5	s.t.	9.5	3.2	12.7	13.2	100.5
13	1A	0.3	68.7	18.1	0.17	0.0	0.2	t	9.8	3.1	12.9	13.1	100.4
14	1A	0.3	68.5	17.8	0.08	s.t.	0.2	0.1	10.1	2.6	12.7	13.0	99.7
15	1A	0.4	67.0	19.4	0.02	0.0	0.7	s.t.	10.2	2.9	13.1		
	3	0.3	67.4	18.1	0.14	0.0	0.1	0.1	11.2	2.5	13.7		
	Av.	0.4	67.2	18.8	0.08	0.0	0.4	0.0	10.7	2.7	Av. 13.4	13.8	100.3
16	1A	0.3	69.1	17.7	0.09	0.0	0.3	—	10.5	2.5	13.0	13.3	100.5
17	1A	1.2	65.2	19.7	0.15	s.t.	0.3	s.t.	12.2	1.2	13.4	13.7	99.9
18	1A	0.3	65.1	19.5	0.20	0.0	0.3	0.0	12.3	2.6	14.9		
	1B	0.4	66.2	18.4	0.15	0.0	0.4	0.1	12.4	2.6	15.0		
	2	0.5	65.6	18.9	0.08	0.0	0.3	0.0	12.4	2.8	15.2		
	Av.	0.4	65.6	18.9	0.14	0.0	0.3	0.0	12.4	2.7	Av. 15.0	15.4	100.4
19	1A	0.2	64.9	19.6	0.08	0.0	0.3	s.t.	13.0	2.0	15.0		
	1B	0.3	65.4	18.5	0.15	0.0	0.3	0.1	13.4	1.8	15.6		
	2	0.4	65.3	18.9	0.05	0.0	0.2	0.0	13.2	2.1	15.3		
	3	0.3	65.1	18.8	0.18	0.0	0.0	0.2	13.1	2.0	15.1		
	Av.	0.3	65.2	18.9	0.10	0.0	0.2	0.1	13.2	2.0	Av. 15.2	15.5	100.0

NOTE: Results reported under 1A were obtained by rapid, routine methods involving single evaporations and precipitations, while those reported under 1B were obtained by methods involving evaporations, precipitations, and other precautions necessary to insure greater accuracy.

B. Chemical Composition

Chemical analyses of all samples were made at the Bureau of Standards and samples Nos. 10, 15, and 19 were analyzed also by an industrial laboratory.[1] The results are given in Table IV. Values for group averages are given in Table V and some general observations in Table VI. With the exception of sample No. 1 (a nearly pure soda feldspar-albite) all of the feldspars tested can be considered as so-called "potash feldspars."[2] The K_2O content of the potash feldspars varies from 4.4 to 13.1%; the Na_2O and SiO_2 vary, practically inversely, from 5.7 to 1.2% and 73.5 to 65.1% respectively; and the Al_2O_3 varies from 14.9 to 19.7%.

TABLE V
(Feldspar No. 1 not included)

Group	Feldspars included in group	K_2O per cent	K_2O+Na_2O per cent	Total alkalis per cent	Uncombined SiO_2 per cent (average)
D	2–9 incl.	4.4– 9.0	10.1–12.0	10.6–12.9	18.6
E	10–17 "	9.1–12.2	12.4–13.4	13.0–13.8	11.0
F	18 and 19	12.3–13.1	15.0–15.1	15.3–15.4	2.0

C. Softening Range

The specimens for this test were prepared by pressing dampened feldspar into a small crucible ($\frac{9}{16}$ inch high and top and bottom inside diameters $\frac{3}{4}$ by $\frac{7}{16}$ inch respectively) the bottom of which had been ground off to facilitate removal of the specimen. A light machine oil was used to prevent sticking to the crucible. The material was pressed by hand, using the rubber tipped end of a lead pencil. Each specimen was set, large diameter down, on a small vitrified tile preparatory to firing. The specimens were fired in a secondary muffle placed in a gas-fired, recuperative, downdraft, semimuffle kiln, and the necessary precautions were taken to insure temperature uniformity and control. The kiln was usually started about 4 P.M. and allowed to heat up over night without attention. By morning the temperature had reached 900°C ± 75° and was then controlled so as to rise at approximately 20° per hour to within "2 cones" (about 50°) of the cone at which the specimens were to be fired. The temperature was then held at this point until the desired cone was down, when the tile bearing the feldspar specimens was withdrawn. A separate firing was made for each cone and observations indicated that the temperature gradient, in the muffle, in no case exceeded $\frac{1}{2}$ cone (10 to 15°C).

The results are given in Fig. 3. Progress of softening was judged by the mattness of the surface, rounding of the upper edges, glossiness

[1] Champion Porcelain Co., Detroit, Mich.

[2] Purely arbitrary expression

of the surface (indicated in the drawing by a "reflection"), "squatting" of the specimen, and finally by its fusion and flow into the form of a "button." It is obvious that the beginning and length of the temperature deformation range are determined primarily by the K_2O–Na_2O ratio. The cone at which surface mattness disappears increases from cones 4–5, for the potash spars lowest in K_2O content (Nos. 2 and 3), to cone 10 for feldspar No. 19. At the same time the interval between "disappearance of mattness," "appearance of glossiness," and decided rounding of the corners shortens materially although the change is

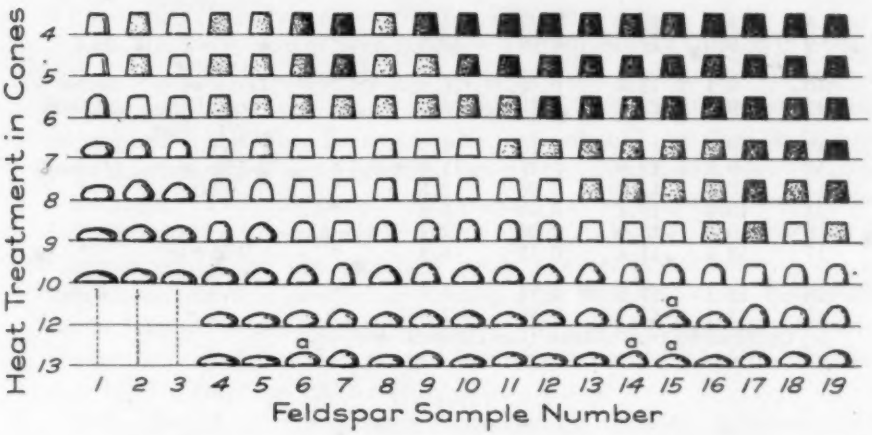

FIG. 3.—Drawing illustrating appearance of various feldspar specimens after the so-called "button test" for determining softening range.

not a perfectly gradual one. The outstanding exception is feldspar No. 8, which has an unusually high Fe_2O_3 content (0.37%) and also a rather high total alkali–K_2O ratio, and low uncombined SiO_2, as compared with the other samples with about the same percentage of K_2O. In general the results show that refractoriness increases, and the softening range decreases, with increase in K_2O, but that these relations may be influenced by Fe_2O_3 (Ex. No. 8) and SiO_2 (Ex. Nos. 1, 3, and 8). General properties of the samples, as related to softening range and appearance of the fused material, are given in Table VI.

D. Softening Point

The softening points were determined with specimens of feldspar made into cones of the size and shape generally used in making the large standard pyrometric cones. Results are reported in terms of Orton cones, the softening "point" being considered as that stage

TABLE VI

GENERAL PROPERTIES AS RELATED TO COLOR AND SOFTENING RANGE

Feldspar No.	K_2O per cent	K_2O+Na_2O per cent	Fe_2O_3 per cent	Free SiO_2 (*a*) per cent	Softening range	Color	Grind
1	0.9	10.9	0.22	2.8	Long	Ivory	Medium
2	4.4	10.1	0.05	21.8	Medium	White Semi-opaque	"
3	5.2	10.9	0.16	11.4	Long	Light gray	Coarse
4	6.4	10.3	0.12	20.4	Medium	Gray Semi-opaque	Fine
5	7.3	10.7	0.11	21.2	"	White Opaque	Coarse
6	7.5	10.8	0.12	20.0	"	Light gray	Medium
7	7.6	10.4	0.19	25.1	"	Pink Semi-opaque	"
8	8.4	12.0	0.37	11.3	"	Dark gray	"
9	9.0	12.0	0.09	17.6	"	White Opaque	"
10	9.1	12.4	0.10	10.6	"	Dirty white	Coarse
11	9.1	12.5	0.16	12.4	"	Very light gray; yellow	Medium
12	9.5	12.7	0.10	12.5	"	White	Fine
13	9.8	12.9	0.17	12.0	"	Light gray	Medium
14	10.1	12.7	0.08	12.6	"	White	"
15	10.7	13.4	0.08	8.5	"	"	"
16	10.5	13.0	0.09	12.7	Short	"	"
17	12.2	13.4	0.15	6.9	"	White to semiclear	"
18	12.3	15.0	0.14	1.9	"	White	Coarse
19	13.1	15.1	0.10	2.2	"	Clear	"

(*a*) Obtained by recalculation from chemical analyses.

TABLE VII

SOFTENING POINTS

(All values given in terms of cone numbers)

Feldspar No.	Laboratory No. 1	2 First test	2 Second test	4	5	Variation (total)	Variation best 4 out of 5 (total)	Average softening point
1	5 hd	4 hd	4 hd	5	3	2½	2	4
2	–	–	5	–	–	–	–	(5)
3	5	4	4 hd	4	3	2	1	4
4	6	6 hd	6 hd	6	6	½	½	6
5	6 hd	3	4 hd	5	6	3	2	5
6	7 hd	7 hd	7 hd	7	6	1	½	7 hd
7	7 hd	8 hd	7	8	7	1½	1	7
8	6 hd	6 hd	5	–	–	½	–	6 hd
9	–	–	7	–	–	–	–	(7)
10	7 hd	7 hd	7 hd	6	7	1	½	7 hd
11	7 hd	7 hd	7 hd	7	6	1	½	7 hd
12	7 hd	7	7 hd	8	5	3	1½	7
13	9 hd	8 hd	7	8	7	1½	1	8
14	8 hd	8 hd	8 hd	8	7	1	½	8 hd
15	8	8	8	10 hd	8	1½	0	8
16	9 hd	8 hd	8 hd	9	7	2	1½	8
17	9	10 hd	10 hd	10 hd	9	½	½	10 hd
18	8	8 hd	8 hd	8	8	½	½	8
19	9	9 hd	9	10 hd	9	1	½	9
				Average variation		1½	1	

hd: half down.
All values given to the nearest half cone.

in the softening range at which the cone has bent sufficiently to bring the tip on a level with the top surface of the plaque in which the cone is mounted. Tests were made by the Bureau and three coöperating industrial laboratories (Table VII), the numbers used to designate the laboratories being the same as used in Table II. The information available regarding details of the methods is limited:

Lab. No. 1.—"The cones were made up with dextrine water to the standard dimensions, *i.e.*, three-sided pyramids 2⅞ inches high and $\frac{3}{16}$ inch across the base of each face. The cone deformation was studied and interpreted in terms of standard Orton cones as they advanced into a gas-fired tunnel kiln at the rate of 200°C per hour."

Lab. No. 2 (Bureau of Standards).—The cones were formed in plaster molds, using the feldspar dampened with a dilute solution of dextrine. Preliminary runs were made in a gas-fired furnace to determine the approximate softening point of each feldspar and the final tests were conducted with the same furnace "set-up" as described under "Softening Range." The temperature was raised to 1000°C at the rate of about 50° per hour and thereafter at 20° per hour. The plaques, bearing the feldspar cones and the standard cones nearest in softening point as determined by the preliminary runs, were removed from the muffle as the feldspar cones reached their end point. The temperatures, under the conditions of this test, ranged from approximately 1150°C for cone 3 to 1250°C for cone 10 "half-down."

Lab. No. 4.—"The fusion" (softening) "points reported were determined by firing standard cones of the various feldspars in a surface combustion furnace, provided with a muffle, along with the appropriate standard cones."

Lab. No. 5.—"We made several softening point tests under slightly different conditions, the results of which check very well among themselves."

The results reported, and variations obtained, are given in detail in Table VII. Considering the widely different methods used, it is rather surprising that the variations are no greater.

E. Fusion Points

No data have been obtained to date.

F. True Specific Gravity

These determinations were made on the material, as received, by the pycnometer method;[1] the results are given in terms of water

[1] For "Standard Method for True Specific Gravity" see the 1922 report of the Standards Committee of the AMERICAN CERAMIC SOCIETY, published in the *1921–22 Year Book* of the SOCIETY.

at 30°C. For maintaining this temperature an electrically controlled water bath was used. The samples, averaging about 6 grams, were dried over night at 110°C.

The detailed results are given in Table VIII, the average values varying from 2.635 for Sample No. 1 (soda feldspar) to 2.572 for Sample No. 19 (a relatively pure potash feldspar). Larsen[1] gives 2.605 for the specific gravity of albite, and 2.56 for orthoclase.

No determinations have been made on the various samples after partial and after complete fusion.

G. Thermal Expansion

No determinations have been made.

TABLE VIII
SPECIFIC GRAVITY

Results given in terms of equal volumes of water at 30°C. Temperature controlled by bath (water) with thermostat holding temperature within 1°C

Feldspar	Sp. Gr.	Check Sp. Gr.	Diff.	Average
1	2.634	2.636	0.002	2.635
2	2.621	—	—	2.621
3	2.613	2.612	0.001	2.613
4	2.621	2.616	0.005	2.619
5	2.611	2.610	0.001	2.611
6	2.611	2.609	0.002	2.610
7	2.612	—	—	2.612
8	2.593	—	—	2.593
9	2.596	—	—	2.596
10	2.602	2.601	0.001	2.602
11	2.601	2.600	0.001	2.601
12	2.600	2.598	0.002	2.599
13	2.594	2.595	0.001	2.594
14	2.590	2.591	0.001	2.590
15	2.585	2.590	0.005	2.587
16	2.590	2.592	0.002	2.591
17	2.572	2.572	0.000	2.572
18	2.585	2.581	0.004	2.583
19	2.571	2.573	0.002	2.572
		Average diff.	0.002	

H. Relative Viscosity While Molten

No determinations have been made.

I. Petrographic Analysis

A comprehensive study of the composition of the various feldspars as determined by petrographic means, and of the relative accuracy of a number of methods of analysis, have been completed by H. Insley and the results are presented in a separate report.[2]

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[1] E. S. Larsen, "The Microscopic Determination of Non-opaque Minerals," U. S. Geol. Surv., *Bull.*, No. 679 (1921).

[2] Paper in course of preparation.

II. Tests on Bodies in Which the Feldspar Is the Only Variable Component

The compositions of the "semivitreous" body and glaze and vitreous body and glaze used in this study are given in Table IX. For comparison the typical bodies suggested by the Advisory Committee to the Bureau are also given. These bodies were not suggested until after the work reported on here was nearly completed; it is thought that the compositions used may also be considered as typical.

The vitreous body and glaze mature at cone 12 (the glaze is good also at cone 10) and satisfactory glazed specimens were obtained either by the "one-fire" or "two-fire" process. The semivitreous body matures at cones 8–9 and the glaze at cone 6.

TABLE IX

BODIES

	Used by Bureau percent		Suggested by Committee (a) percent
Vitreous Bodies			
Ball clay	7.5	Great Beam English	8.0
Kaolin	8.0	Florida (E. P. K.)	6.0
China clay	29.0	A-1 English	22.0
		MGR-2 "	11.0
Flint	36.0	National Silica Co.	34.5
Whiting	1.5	English Cliffstone	2.5
Feldspar	18.0		16.0
Semivitreous Bodies			
Ball clay	15.0	Higman's No. 12	13.0
Kaolin	8.0	Florida (Edgar)	6.0
		North Carolina (Harris)	9.0
China clay	29.0	Pooles No. 1	12.5
		Pooles No. 10	12.0
Flint	34.0		35.0
Feldspar	14.0	Maine	12.5

GLAZES

	Vitreous per cent	Semivitreous per cent	Frit	per cent
Frit	—	30.9	SiO_2	59.2
Feldspar	37.0	30.9	Florida kaolin	5.4
$CaCO_3$	13.8	13.8	Borax	10.6
$BaCO_3$	8.0	—	Boric acid	22.4
$MgCO_3$	5.0	3.4	$CaCO_3$	2.2
Florida kaolin	10.6	—		
SiO_2	21.8	—		
SnO_2	3.8	—		
PbO	—	17.9		
ZnO	—	3.2		

(a) These bodies were suggested as typical commercial bodies by the Advisory Committee to the Bureau of Standards.

The bodies were prepared by wet grinding for six hours, sieving, removal of iron from the slip by magnetic separation, filterpressing, and storage of the filterpress cakes in a damp closet until used. Since 19 feldspars are being studied, there were 19 bodies and 19 glazes of each type. The bodies are designated by *V* for vitreous, *SV* for "semivitreous," and the number of the body and of the glaze indicates the feldspar used in compounding it.

TABLE X

Body No.	Semivitreous Bodies (Values are average of 3 specimens)									Vitreous Bodies (Values are average of 3 specimens)						
	Porosity				Volume Shrinkage					Porosity			Volume Shrinkage			
	Cone 4 in 54 hrs. (per cent)	Cone 6 in 30½ hrs. (per cent)	Cone 8 in 40 hrs. (per cent)	Cone 12 in 48½ hrs. (per cent)	Cone 4 in 54 hrs. (per cent)	Cone 6 in 30½ hrs. (per cent)	Cone 8 in 40 hrs. (per cent)	Cone 12 in 48½ hrs. (per cent)	Cone 12 in 5 days (per cent)	Cone 6 in 30½ hrs. (per cent)	Cone 8 in 40 hrs. (per cent)	Cone 12 in 48½ hrs.	Cone 6 in 30½ hrs. (per cent)	Cone 8 in 40 hrs. (per cent)	Cone 12 in 48½ hrs. (per cent)	Cone 12 in 5 days (per cent)
1	19.4	12.8	4.8	–	17.9	24.9	28.9	33.9	35.4	7.0	1.3	(a)	27.0	29.6	30.8	31.3
2	21.8	15.9	10.9	1.3	16.1	22.0	25.7	32.8	35.4	8.8	0.5		26.2	30.3	30.8	31.9
3	21.1	12.3	6.3	–	16.5	21.0	24.5	33.6	34.1	7.2	0.0		26.9	32.7	31.5	28.4
4	21.4	15.2	8.5	0.5	17.0	22.4	28.4	32.0	34.5	6.2	0.1		25.7	28.7	28.4	30.6
5	22.6	15.9	5.1	*	17.4	23.2	29.5	32.6	34.7	9.3	0.3		27.3	32.4	32.0	31.3
6	22.6	16.5	5.7	*	17.3	24.9	30.1	33.2	37.0	9.4	0.1		24.7	32.9	31.0	32.4
7	24.7	16.4	11.3	*	18.5	24.8	28.0	33.3	36.3	6.7	0.8		27.5	31.5	31.6	32.6
8	21.7	12.5	—	*	—	23.1	26.6	33.7	35.4	6.5	0.4		29.3	32.1	30.1	21.7
9	23.3	17.3	12.7	*	14.5	22.0	25.0	32.0	35.5	12.0	2.0		24.7	31.8	32.5	29.3
10	23.1	13.3	10.5	*	16.4	23.5	27.9	33.0	35.3	7.8	0.7		28.9	31.9	31.4	25.7
11	22.5	14.1	6.4	*	17.8	21.2	30.1	33.5	35.2	9.7	0.1		24.9	31.0	30.2	29.1
12	23.0	15.0	10.0	*	16.4	21.4	23.9	30.7	35.4	6.2	0.1		27.1	30.7	31.1	28.0
13	23.2	12.5	11.7	*	16.5	24.6	27.4	33.2	35.5	7.3	1.1		25.9	30.1	30.2	28.4
14	21.8	12.2	8.0	*	18.7	24.2	28.0	32.3	35.4	9.4	—		26.4	—	32.9	29.4
15	23.6	12.3	8.9	*	18.0	22.0	25.8	33.0	35.0	7.3	0.4		30.0	32.4	31.3	27.3
16	22.9	15.5	13.1	*	20.0	25.0	28.2	30.7	36.4	12.6	—		24.6	29.6	31.1	30.4
17	19.6	13.8	9.7	*	15.3	19.9	25.6	31.5	37.0	11.0	1.2		26.6	32.2	32.7	29.0
18	19.8	14.4	10.2	*	16.0	23.6	25.2	31.9	35.1	7.2	0.9		26.8	29.9	30.0	27.1
19	22.6	14.7	6.3	*	17.0	23.6	25.2	33.1	35.7	5.3	0.1		28.7	31.8	31.6	28.5

* Zero porosity.
(a) All bodies of zero porosity

A. Firing Behavior and Maturing Range

These properties were determined by firing 1 by 1 by 2-inch bars of the vitreous and "semivitreous" bodies to a number of temperatures and observing the final porosity and change in volume. The results are given in Table X, the values for volume shrinkage being the average of determinations on five specimens and those for porosity are the average for three specimens. Volumes were determined by the mercury displacement method. Porosities of the fired specimens were calculated using values obtained by weighing the specimens in air after drying at 110°C and weighing in air and suspended in water after boiling in water five hours and cooling in the water.

The relations of these volume shrinkage (during firing) and porosity values to fineness and chemical composition are given in Table XI. The data as correlated in this table indicate the following: (1) fired porosity of *SV* bodies reaches a maximum with feldspars intermediate in fineness, K_2O content, and uncombined SiO_2; and (2) volume shrinkage of both *V* and *SV* bodies decreases with increase in fineness, K_2O content, and uncombined SiO_2 (the exceptions being with *SV* bodies, Groups A, B, C, and *b* and *c*). While the relations are fairly consistent, the variations in porosity and shrinkage involved are so small as to make their significance and industrial importance problematical. Their significance can be questioned because the average variation between results on specimens of the same body was approximately 2.0% for shrinkage determinations and 1.5% for porosity determinations,[1] and the industrial importance of 1 to 2% variation (total) in porosity and volume shrinkage would not affect the manufacture of the bulk of ceramic whiteware bodies.

The per cent volume shrinkage of the vitreous bodies fired to cone 12 in five days, being decidedly less in most cases than the shrinkage when fired to cone 12 in two days (Table X), indicates that the bodies were somewhat "overfired," *i.e.*, that a vesicular structure had begun to form, which is a condition held to be highly undesirable because of decreased mechanical strength.[2] Several of the bodies (Nos. 3, 5, 6, 8, 10, and 11) apparently were overfired after the two-day fire to

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[1] Probably due to the many variables involved in the making of handpressed specimens. Check determinations, using cast specimens, while agreeing very well for specimens of the same body, showed average ± variations of 1.5% from the average determinations on the 1 by 1 by 2-inch handpressed specimens.

[2] H. H. Sortwell, "The Effect of Variation in Firing on the Physical Properties of Vitreous China Bodies," *Jour. Amer. Ceram. Soc.*, **6** [8], 915 (1923).

For data on the viscosity of porcelain bodies see Bur. of Stand., *Tech. Paper*, No. 30.

The vitreous body and feldspar No. 6, of this investigation are practically equivalent to Body No. 16 and the feldspar used in the work reported in *Tech. Paper*, No. 30.

TABL

RESULTS OF OBSERVATIONS MA

Feldspar		Vitreous Body Fired to cone 12 in 5 days						5 Fired
1	T	.039	.059	.079	.095	.113	.083	.1
	L					9.3		
	D	1.31	1.62	1.91	2.13	2.40	1.01	1.0
2	T	.039	.060	.080	.095	.113	.083	.1
	L					5.3		
	D	1.49	1.78	2.13	2.34	2.72	1.10	1.1
3	T	.041	.061	.079	.098	.117	.090	.1
	L					6.7		
	D	1.43	1.71	1.89	2.19	2.48	0.93	1.0
4	T	.041	.060	.076	.093	.111	.083	.0
	L					6.0		
	D	1.46	1.80	2.04	2.28	2.58	1.03	1.1
5	T	.040	.058	.078	.096	.113	.086	.1
	L					6.9		
	D	1.34	1.62	1.82	2.11	2.37	0.95	1.0
6	T	.039	.059	.079	.097	.114	.084	.1
	L					7.2		
	D	1.33	1.63	1.93	2.15	2.43	1.02	1.0
7	T	.040	.060	.079	.095	.113	.080	.1
	L					6.9		
	D	1.45	1.67	1.98	2.22	2.48	0.96	1.0
8	T	.040	.060	.078	.096	.113	.080	.0
	L					7.6		
	D	1.46	1.74	1.98	2.19	2.44	1.02	1.1
9	T	.040	.060	.079	.096	.113	.082	.1
	L					10.6		
	D	1.37	1.62	1.88	2.05	2.27	0.96	1.0
10	T	.041	.060	.078	.096	.112	.088	.1
	L					10.8		
	D	1.40	1.63	1.82	2.00	2.22	0.91	1.0
11	T	.041	.063	.081	.101	.117	.081	.1
	L					9.0		
	D	1.40	1.70	1.89	2.11	2.38	0.93	1.0
12	T	.040	.060	.079	.095	.113	.090	.1
	L					11.1		
	D	1.40	1.62	1.85	2.05	2.28	0.97	1.0
13	T	.042	.062	.083	.103	.119	.086	.1
	L					8.0		
	D	1.42	1.70	1.96	2.15	2.55	0.96	1.0
14	T	.039	.058	.079	.096	.114	.087	.1
	L					8.7		
	D	1.37	1.62	1.88	2.08	2.37	0.90	0.9
15	T	.045	.063	.080	.099	.116	.080	.1
	L					11.6		
	D	1.38	1.60	1.77	2.00	2.23	0.89	0.9
16	T	.040	.059	.077	.095	.112	.077	.0
	L					14.4		
	D	1.29	1.56	1.76	1.94	2.20	0.89	0.9
17	T	.042	.062	.081	.099	.116	.092	.1
	L					13.2		
	D	1.33	1.57	1.76	1.96	2.17	0.93	1.0
18	T	.039	.059	.079	.096	.115	.088	.1
	L					12.5		
	D	1.35	1.54	1.75	1.97	2.22	0.90	0.9
19	T	.042	.062	.082	.100	.115	.090	.1
	L					12.5		
	D	1.37	1.62	1.80	2.04	2.25	0.85	0.9

T = thickness in inches
L = relative values for translucency
D = photographic density

TABLE XII

ATIONS MADE WITH MARTENS PHOTOMETER

50 feldspar—50 SiO_2 Fired to cone 12 in 5 days					50 feldspar—50 SiO_2 Fired to cone 10 in 45½ hrs.				
.083	.102	.116	.127	.146	—	.096	.113	.131	.147
				5.5					2.8
1.01	1.06	1.12	1.15	1.26	—	1.24	1.40	1.43	1.55
.083	.101	.114	.130	.150	.076	.097	.116	.134	.148
				4.5					3.4
1.10	1.11	1.21	1.21	1.36	1.17	1.21	1.29	1.42	1.46
.090	.104	.123	.140	.151	.083	.100	.119	.132	.147
				6.7					4.3
0.93	1.01	1.03	1.09	1.17	1.09	1.21	1.27	1.29	1.37
.083	.099	.114	.130	.150	.076	.090	.109	.126	.146
				6.2					1.6
1.03	1.11	1.20	1.25	1.33	1.32	1.37	1.57	1.65	1.80
.086	.105	.124	.140	.156	.073	.090	.109	.128	.145
				6.5					4.2
0.95	1.01	1.09	1.16	1.21	1.04	1.10	1.16	1.17	1.34
.084	.104	.122	.138	.150	.093	.110	.124	.135	.150
				5.8					3.1
1.02	1.08	1.15	1.18	1.25	1.20	1.27	1.35	1.43	1.50
.080	.100	.112	.124	.145	.075	.095	.112	.130	.144
				5.4					1.5
0.96	1.09	1.12	1.15	1.27	1.18	1.38	1.52	1.65	1.82
.080	.099	.114	.128	.148	.075	.094	.108	.130	.148
				5.0					1.9
1.02	1.13	1.17	1.23	1.30	1.14	1.31	1.41	1.57	1.73
.082	.105	.110	.135	.151	.077	.093	.108	.125	.144
				5.3					3.1
0.96	1.09	1.09	1.21	1.27	1.13	1.19	1.35	1.44	1.51
.088	.110	.125	.143	.157	.078	.093	.111	.126	.147
				6.1					3.9
0.91	1.05	1.09	1.16	1.22	1.13	1.18	1.25	1.35	1.41
.081	.100	.127	.130	.151	.074	.099	.115	.131	.151
				5.8					4.5
0.93	1.03	1.13	1.19	1.22	1.06	1.09	1.21	1.27	1.35
.090	.107	.125	.142	.160	—	—	—	—	—
				6.5					—
0.97	1.04	1.10	1.14	1.22	—	—	—	—	—
.086	.105	.123	.139	.157	.080	.100	.115	.130	.146
				6.0					3.1
0.96	1.03	1.10	1.16	1.26	1.10	1.11	1.24	1.38	1.46
.087	.104	.115	.137	.157	.082	.104	.120	—	.152
				6.7					4.1
0.90	0.99	1.02	1.11	1.17	1.09	1.17	1.31	—	1.46
.080	.100	.120	.134	.150	.070	.090	.106	.120	.130
				8.2					3.8
0.89	0.95	0.98	1.00	1.09	1.07	1.16	1.25	1.36	1.42
.077	.095	.112	.130	.144	.080	.097	.113	.129	.147
				7.9					3.7
0.89	0.95	1.00	1.05	1.10	1.07	1.17	1.25	1.35	1.48
.092	.108	.123	.143	.158	.088	.104	.122	.140	.155
				6.4					2.0
0.93	1.00	1.06	1.14	1.20	1.25	1.38	1.47	1.60	1.67
.088	.108	.124	.146	.160	.080	.098	.116	.133	.150
				7.6					4.0
0.90	0.97	1.01	1.07	1.11	1.07	1.13	1.24	1.32	1.40
.090	.105	.125	.138	.157	.080	.099	.116	.136	.154
				10.2					3.4
0.85	0.90	0.98	1.01	1.07	1.09	1.16	1.26	1.38	1.45

cone 12. It is not evident why body No. 1 (containing soda feldspar) did not overfire since this feldspar is the least "refractory" (lowest softening point) of the nineteen tested. Insofar as overfiring is concerned there is apparently an advantage in using feldspars of relatively high uncombined SiO_2 content. Average values show 3.1% less shrinkage (*i.e.*, less than after the two-day fire) for the *V* bodies fired to cone 12 in five days and made with feldspar containing uncombined SiO_2 varying from 1.9 to 13%, and 0.7% less shrinkage for the group of bodies containing feldspar with uncombined SiO_2 varying from 17 to 25%. The higher average percentage of uncombined SiO_2 of the feldspars Group D (Table V) probably accounts for the less pronounced tendency of the corresponding bodies to overfire as compared with the bodies containing feldspars of Groups E and F. It is also worthy of note that the body containing feldspar No. 8, with the highest percentage of iron (0.37%) showed the greatest tendency to overfire.

B. Color and Translucency

1. Color Visual inspection of thin glazed butters showed no difference in color of the various bodies by reflected light. This was checked by determinations with the Pfund colorimeter,[1]

TABLE XI

Group (Table III)		Semivitreous (*SV*) bodies (cone 8) (per cent)	Vitreous (*V*) bodies (cone 12)[a] (per cent)	Group (Table III)	Semivitreous (*SV*) bodies (cone 8) (per cent)	Vitreous (*V*) bodies (cone 12)[a] (per cent)	Group (Table V)	Semivitreous (*SV*) bodies (cone 8) (per cent)	Vitreous (*V*) bodies (cone 12)[a] (per cent)
A	Porosity	8.6	—	a	8.5	—	D	8.7	—
	Volume shrinkage	32.5	31.7		27.6	31.8		27.4	32.5
B	Porosity	10.0	—	b	9.4	—	E	9.8	—
	Volume shrinkage	32.6	30.8		26.4	30.7		27.1	31.4
C	Porosity	8.0	—	c	8.7	—	F	8.2	—
	Volume shrinkage	32.9	30.7		26.9	29.9		25.2	30.8

[a] Firing made in 48½ hours

the only noteworthy result being the general observation that the bodies were deficient in blue.

2. Translucency The "translucency" of the nineteen vitreous bodies, and of 50–50 feldspar–quartz mixtures,

[1] "A New Colorimeter for White Pigments and Some Results Obtained by Its Use," A. H. Pfund, *Proceedings A. S. T. M.*, Part II, p. 440–448 (1920).

was determined by means of the Martens photometer.[1] The values obtained may be expressed in terms either of density or transmission (Table XII). The zero reading of the instrument (transmission 100% and density zero) is the dial reading of 45°.[2] *Transmission* (or translucency) T is the square of the tangent $(45-\alpha)$ where α is the angle, read on the dial, through which the nicol prism must be turned from the zero position to "match" the light transmitted through the specimen. *Density* is equal to $-\log T$.

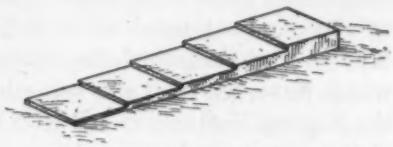

FIG. 4.—Type of vitreous body specimen used in observing relative light transmission.

The form of specimens used is shown in Fig. 4 and the heat treatment given them, together with density and transmission values, are given in Table XII. The specimens were made by handpressing in a steel mold, a dilute solution of gum arabic being used to give the 50–50 spar–flint mixes the necessary workability. In the tests the incident light was diffused and the surfaces of the specimens were not ground; consequently, the values obtained are purely relative. Furthermore, only one, or occasionally two, determinations were made on duplicate specimens so that an appreciable experimental error (probably $\pm 10\%$) is to be expected. Since the thicknesses of any particular "step" (see Fig. 4) did not vary more than $\pm 5\%$ for all the specimens, mathematical reduction of the relative translucency values to a unit thickness did not seem justified. The translucency (or light transmission) values (L, Table XII) are, therefore, compared without reference to the specimen thickness.

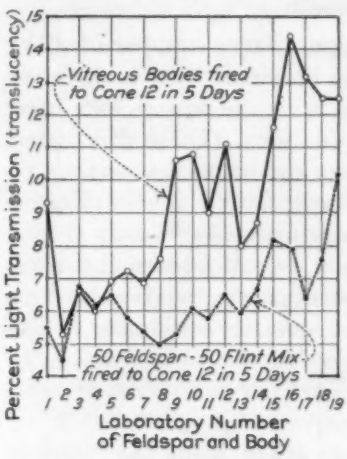

FIG. 5.—Light transmission values plotted to show relative effect of various feldspars on this property of vitreous bodies.

The relation between feldspar composition and the light transmission of the corresponding 50–50 mixes fired to cone 10 is very erratic but a fairly definite tendency is shown by the mixes and bodies fired to cone 12. For convenience the values are plotted in Fig. 5.

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[1] *Physikalische Zeits.*, **1**, 299–303 (1900).

[2] The apparatus actually has four zero positions (45°, 135°, 225°, and 315°) but only the first is used.

The soda feldspar (No. 1) apparently produces a body equal in translucency to those containing feldspars of intermediate K_2O content, and the translucency of the potash feldspar bodies (Nos. 2 to 19) increases fairly directly with K_2O. The relation, while irregular, is sufficiently definite to warrant the conclusion that the per cent K_2O, or the per cent total alkali which practically parallels the per cent K_2O, is the predominating factor controlling translucency of bodies which have received the same heat treatment. The translucency of the highest K_2O feldspar bodies is appreciably higher than that of the soda feldspar body.

The translucencies of the 50–50 feldspar–flint mixes (Fig. 5) show a slight and irregular tendency toward increase with the use of feldspars of increasing K_2O content. The method of test might prove useful in determining rates of solution of flint by feldspar if the necessary precautions were taken to prevent devitrification and to eliminate the unequal reflection of light from the surfaces of the specimens by grinding these surfaces to practically the same "smoothness."[1]

C. Mechanical Strength

During the early part of the investigation a large number of disks (3 inches diameter by $\frac{1}{4}$ inch, and 5 inches diameter by $\frac{1}{4}$ inch) were "jiggered" of each body and fired together with the square bars used for porosity and volume shrinkage determinations. These disk specimens were tested for resistance to chipping and impact according to the method described by Sortwell[2] and incorporated in the United States Government Specification for vitrified chinaware.[3] The average results were very nearly the same for all bodies and such variations as were determined showed no apparent relation to any other test results. Also, the variations in values for specimens of the same body usually equalled and often exceeded the variations in the average values for all the bodies. The data are not considered of sufficient significance to warrant publication.

A limited number of tests have since been made, using the "impact bending test."[4] The specimens used in this test are cast rods approximately $\frac{3}{8}$ inch diameter by 5 inches long notched at the center to give a clean break. The notch, *V*, in shape, is $\frac{1}{4}$ inch wide and $\frac{1}{8}$ inch deep; in testing it is placed directly opposite to the point of impact of

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[1] For further data see "An Investigation of the Translucency of Porcelains," C. W. Parmelee and P. W. Ketchum, University of Illinois Bulletin, No. 154 (Vol. XXIII, No. 31, April 6, 1926).

[2] See footnote 2, p. 425.

[3] Bur. Stand., *Circ.*, No. 202.

[4] "Mechanical Testing," Botson and Hyde (published by E. P. Dutton Co.).

the hammer. The span used is four inches. The machine is so designed that the swinging hammer breaks the specimen at the first blow and swings some distance beyond; this distance is a measure of the residual energy in the hammer and, inversely, a measure of the energy required to break the specimen. The results are calculated to foot–pounds of energy required to break a bar of similar material one inch in diameter and are obtained by dividing the value (I) indicated on the calibrated scale of the machine, after impact, by the diameter squared of the specimen tested. No allowance was made for the notch since relative values only were desired.

The notched specimens were also broken transversely (with the knife edge of the straining clevis placed in the notch) and the maximum deflection and load required noted.[1] Having these observations, the following *relative values* were calculated (the values are relative since no allowance was made for the notch):

$$\text{Modulus of rupture} = \frac{LS}{0.392d^3} \text{ lbs./sq. in.}$$

$$\text{Work required to break transversely} = \frac{L\Delta}{d^2} \text{ in.–lbs.}$$

Pliability $= \Delta =$ maximum deflection in inches where:
$L =$ load at center of specimen in pounds
$S =$ span (4 inches in these tests)
$d =$ diameter of specimen in inches (notch not allowed for)

The tests were made on five bodies selected to represent extremes in feldspars (Table XIII). Specimens of each body were fired according to definite schedules involving the four combinations of fast and slow heating and fast and slow cooling. The results, while interesting, will be thoroughly checked before conclusions can be published. The data obtained are summarized in Table XIV.

D. Composition as Determined by Petrographic Means

The following is the report of the only work completed to date (H. Insley):

> No difference in quartz solution or in mullite development could be noted in the vitreous bodies made with feldspars Nos. 1, 2, and 19 (fired to cone 12 in 30 hours). In all three, mullite was well developed and quartz showed evidence of solution, being surrounded by narrow solution rims.

This information, although limited, is interesting since feldspar No. 1 is the soda feldspar, No. 2 the potash feldspar lowest in K_2O, and No. 19 the potash feldspar highest in K_2O content.

[1] For a description of the apparatus used see A. C. Harrison, "A Machine for Transverse Tests of Clay and Glass Laboratory Specimens," *Jour. Amer. Ceram. Soc.*, **8** [11], 774 (1925).

TABLE XIII

General Properties of the Feldspars in the Bodies Used for Studying the Effects of Varying Rates of Heating and Cooling

(The number of the feldspar sample determines the number of the body)

Body No.[a]	Alkali Content of Feldspar K_2O (per cent)	Na_2O (per cent)	$CaO+MgO$ (per cent)	Softening point of feldspar cone	Source of feldspar
1	0.9	10.0	0.7	4	Cecil County, Md.
2	4.4	5.7	0.8	5	Balderson, Ont.
3	5.2	5.7	0.9	4	(blend) Cecil Co., Md. Mitchell, N. C.
10	9.1	3.3	0.8	8 hd	Mitchell Co., N. C.
19	13.1	2.0	0.3	9	Buckingham, Quebec.

[a] Refers to both vitreous (*V*) and semivitreous (*SV*).

E. Effect of Feldspar on Relative "Glaze Fit"

The first series of tests was made using 3 by ¼-inch disks of the vitreous bodies bisque fired to cone 12 and glost fired to cone 10. The specimens used were as follows:

Group		Number of specimens
1	Each body (Nos. 1–19) glazed with the corresponding glaze	95
2	Body 1 and glazes Nos. 17, 18, and 19	15
3	" 2 " " " " " " "	15
4	" 3 " " " " " " "	15
5	" 17 " " " 1, 2, and 3	15
6	" 18 " " " " " "	15
7	" 19 " " " " " "	15

The specimens were quenched in running water (28°C) and heated progressively to the following temperatures until failure by crazing occurred: 175°, 190°, 205°, 220°, and 235°C. Ten quenchings were made from 175° and five from each of the higher temperatures. In practically every case 220° or lower was sufficient to produce crazing.

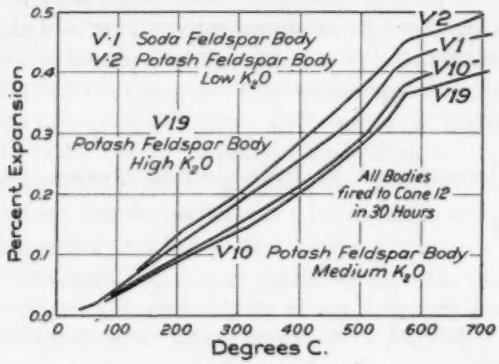

FIG. 6.—Curves showing linear thermal expansion of four vitreous bodies fired to cone 12 in 30 hours and cooled at an average rate of 50° per hour.

The results obtained with specimens of Group 1 are erratic and indicated no discernible effect of the feldspar. The glazes failed rather uniformly after one or two quenchings from either 205 or 220°C.

There is no noteworthy difference in the apparent resistance to crazing of the specimens of Groups 2, 3, and 4. Glazed specimens of

TABLE XIV

EFFECT OF VARIATIONS IN HEATING AND COOLING RATES ON MECHANICAL STRENGTH

Vitreous Body No.	Firing No. 12						Firing No. 13						Firing No. 14						Firing No. 15					
	1	2	3	10	19	Av.	1	2	3	10	19	Av.	1	2	3	10	19	Av.	1	2	3	10	19	Av.
Volume shrinkage (per cent)	36.7	37.4	37.2	38.1	37.6		34.8	35.6	—	36.7	35.9		36.8	36.7	37.1	37.4	36.9		35.5	37.1	35.9	38.9	37.5	
Impact (*a*) lbs./sq. in.	1.09	1.05	1.05	1.05	1.07	1.06	1.11	1.12	—	1.20	1.19	1.15	1.20	1.14	1.17	1.16	1.18	1.17	1.18	1.17	1.19	1.21	1.22	1.19
Work required to break in transverse test (*b*) in.-lbs.	5700	4600	7600	8000	6400	6500	6800	6000	—	10000	8100	7700	7600	8200	8200	7600	7500	7800	8000	7500	11000	6100	7200	8000
Modulus of rupture (*c*) lbs./sq. in.	9400	7300	9100	8200	9400	8700	9900	9400	—	9260	9800	9500	10100	10700	11000	10200	9800	10400	11600	10400	12600	11300	10600	11300
Pliability (*d*) inches	.010	.010	.014	.015	.011	.012	.010	.010	—	.016	.012	.012	.011	.011	.011	.011	.011	.011	.010	.012	.011	.008	.010	.010

Firing 12—fired to cone 12 in 30 hours; cooled from 950° to 450° at 50°/hr.
" 13— " " " 12 " 30 " " " " " " " " 16°/hr.
" 14— " " " 12 " 17 " " " " " " " " 50°/hr.
" 15— " " " 12 " 17 " " " " " " " " 19°/hr.

(*a*) $\frac{I}{d^n}$ (relative values only) (*c*) $\frac{LS}{4 \times 0.0982 d^3}$

(*b*) $\frac{\Delta L}{d^n}$ (relative values only) (*d*) Maximum deflection in inches (relative values only)

bodies 1 and 3 failed at 190° and 205°, while nearly every specimen of body 2 crazed after the first and second quenching from 205°.

Specimens of Groups 5, 6, and 7 were very poor in regard to crazing. The majority of the specimens were crazed on removal from the kiln.

The evident conclusion from these preliminary data is that soda feldspar in the body and potash feldspar in the glaze produce a product of rather good resistance to crazing while potash feldspar in the body and soda feldspar in the glaze seriously decrease resistance to crazing. This may be explained partly by the formation of more feldspathic glass in the soda feldspar bodies, thereby increasing the relative thermal dilatation, and partly by assuming that the thermal dilatation of fused soda feldspar is higher than that of fused potash feldspar and that there would be corresponding effects on the properties of bodies and glazes in which they were used.

This is at least partly verified by the thermal expansion observations reported later (Table XV and Fig. 6) and by the cubical coefficients of expansion of Na_2O and K_2O (10.0×10^{-7} and 8.5×10^{-7} respectively).[1] If the assumptions and data are correct, Na_2O in the body and K_2O in the glaze would obviously "work together" toward a better glaze fit (within certain percentages) while K_2O in the body and Na_2O in the glaze would "work against each other" to produce a condition

TABLE XV

DETAILED DATA GIVING PER CENT EXPANSION AND TEMPERATURE AT WHICH OBSERVED

Body No.	Firing No.												
1	12	A	88	132	226	283	328	408	517	561	604	648	696
		B	.035	.067	.131	.163	.194	.255	.347	.407	.438	.455	.474
	13	A	98	138	215	259	317	392	491	545	618	658	707
		B	.036	.067	.130	.167	.192	.253	.345	.404	.465	.483	.502
	14	A	90	138	219	268	320	392	508	545	596	650	684
		B	.035	.067	.129	.160	.191	.252	.372	.431	.503	.521	.534
	15	A	93	132	206	248	301	380	508	554	606	652	688
		B	.033	.063	.121	.152	.181	.239	.352	.409	.449	.466	.477
2	12	A	88	129	201	246	304	419	494	554	599	652	712
		B	.047	.071	.139	.172	.206	.294	.362	.426	.468	.484	.502
	13	A	78	124	192	238	295	426	501	556	601	660	701
		B	.032	.070	.135	.168	.201	.298	.361	.432	.463	.482	.495
	14	A	86	132	206	246	295	394	505	552	604	640	688
		B	.032	.062	.120	.149	.177	.262	.373	.429	.490	.501	.518
	15	A	93	138	213	262	313	394	512	561	593	650	694
		B	.037	.070	.136	.169	.201	.265	.361	.431	.462	.482	.494
3	12	A	96	155	199	251	317	405	494	549	611	646	701
		B	.039	.075	.100	.145	.186	.254	.330	.390	.434	.440	.462
	13	A	93	144	190	243	307	405	491	556	613	652	703
		B	.037	.072	.105	.139	.162	.238	.303	.368	.400	.413	.432
	14	A	96	148	190	243	301	422	526	552	611	648	686
		B	.036	.070	.102	.135	.168	.263	.357	.389	.445	.457	.470
	15	A	98	148	196	241	298	392	505	556	608	648	686
		B	.036	.069	.102	.135	.166	.328	.352	.414	.451	.464	.476
10	12	A	93	148	196	246	304	399	512	564	601	650	700
		B	.034	.065	.095	.126	.156	.215	.302	.366	.392	.404	.420
	13	A	96	155	199	251	313	392	496	556	599	646	686
		B	.036	.069	.101	.133	.165	.227	.317	.381	.399	.412	.425
	14	A	88	138	219	256	304	415	501	547	606	646	688
		B	.034	.065	.125	.145	.185	.273	.361	.418	.476	.488	.500
	15	A	98	151	192	238	292	417	515	542	604	640	694
		B	.034	.066	.096	.126	.157	.246	.334	.363	.421	.433	.451
19	12	A	88	159	211	268	323	410	517	545	608	648	703
		B	.035	.068	.100	.124	.150	.210	.300	.332	.370	.382	.400
	13	A	102	172	224	—	304	401	526	554	599	648	701
		B	.031	.073	.107	—	.142	.208	.306	.339	.384	.404	.423
	14	A	96	151	190	231	334	405	496	552	599	646	694
		B	.037	.071	.104	.137	.202	.267	.363	.426	.471	.490	.510
	15	A	90	141	224	283	328	401	494	545	606	646	694
		B	.033	.063	.122	.151	.180	.237	.322	.377	.434	.450	.467

A = temperature (°C) at which expansion was observed
B = per cent linear expansion

[1] Winkelman and Schott, *Sprechsaal*, No. 13 (1911). Later determinations by Turner, *Jour. Soc. Glass Tech.* (1923) place the value for Na_2O at 12.9×10^{-7}.

conducive to crazing. Also, with the same feldspar in the body and glaze, there may be a "paralleling" effect under which condition other factors such as the percentage of uncombined SiO_2 might control the resistance to crazing.

The work is being checked, using in addition to the previously tested combinations, a series in which body No. 10 is glazed with each of the 19 glazes and glaze No. 10 is applied to each of the 19 bodies. The entire set of body and glaze combinations will also be tested with the "semivitreous" bodies and glazes.

F. Thermal Expansion of Bodies

The thermal expansion observations were made by the interferometer method,[1] using triangular specimens handpressed in plaster molds and fired as described in Table XV. Observations to date have been confined to the vitreous bodies described in Table XIII and typical results are illustrated by the curves in Fig. 6. Duplicate runs have been made on specimens from firing No. 12 only; the maximum variation found was $\pm 5\%$ and most of the observations checked well.

The limited data do not justify generalizations but they indicate that the expansion is higher when the bodies are fired rapidly, and also that the expansion of the body increases with increase in the percentage of Na_2O in the feldspar used. The one exception to the second conclusion as shown by the data (Body *V2*) may be explained by the high uncombined SiO_2 content (21.8%) of feldspar No. 2. The uniformly higher per cent expansion is undoubtedly caused by the greater percentage of quartz and tridymite, or cristobalite, present; the increased rate of expansion in the range 550° to 600° is very noticeable and there is also a decided increase in the rate between 100° and 200°, particularly for the slowly fired bodies (firings 12 and 13). Body *V2* is also an exception to the first conclusion, but the reason has not been found in the results available.[2]

Summary

Following an outline of the general study of whiteware raw materials of which the investigation of feldspar forms a part, results are given obtained by: screen analyses and air elutriation, chemical analyses, and softening range, softening point, and true specific gravity de-

[1] George E. Merritt, "Application of the Interferometer to Measurements of the Thermal Dilatation of Ceramic Materials," Bur. Stand., *Sci. Paper*, No. 485.

[2] For other data see information and references in articles by: A. S. Watts, *Trans. Amer. Ceram. Soc.*, **13**, 406 (1911). R. C. Purdy and A. P. Potts, *Trans. Amer. Ceram. Soc.*, **13**, 431 (1911); H. Kohl, *Ber. der Deut. Ker. Gesell*, **13** [6], p. 1 (Dec. 1922). A. B. Searle, The Chemistry and Physics of Clays and Other Ceramic Materials (Ernest Benn Limited, London).

terminations of the 19 feldspars included in the study. Results are also given of mechanical strength, color, light transmission, firing behavior, and thermal expansion tests of whiteware bodies in which the feldspars were the only variable component; and, tests of the resistance to crazing of glazed specimens of these bodies.

The results indicate:

1. The residue of commercial ground feldspar on the No. 200-sieve will vary approximately from zero to 7%, on the No. 325 sieve from 3 to 15%, and by air elutriation (0.02 mm separation) from 32 to 55%.

2. Based on chemical composition, the feldspars may be divided into three fairly distinct groups as shown in Table V.

3. The variation in screen analyses made independently by various laboratories may differ sufficiently to make specifications to closer than $\pm 0.5\%$ of little significance.

4. That differences in chemical analyses are sufficient to justify a more extensive and coöperative investigation to determine the cause and control of present variations and the accuracy which can be expected with recognized good analytical methods.

5. Results indicate that refractoriness increases, and the softening range decreases, with increase in K_2O.

6. Softening points range from that of cone 4 for soda feldspar to that of cones 9 to 10 for potash feldspar, and that average variations of one cone can be expected in the results of different laboratories, particularly when no single method is followed by all.

7. True specific gravity of crystalline feldspar ranges from 2.635, for a commercially pure soda feldspar, to 2.572 for a commercially pure potash feldspar.

8. The porosity of "semivitreous" bodies is highest when using feldspars of intermediate K_2O content and the volume shrinkage of vitreous bodies decreases with increase in the K_2O content of the feldspar used. (The results are somewhat erratic and, while consistent, are believed to be of questionable significance).

9. The feldspar has no discernible effect on the color of the body by reflected light.

10. The translucency of vitreous bodies increases (Body No. 1 excepted) with increase in the K_2O content of the feldspar used.

11. Mechanical strength is affected more by the method of firing than by the feldspar.

12. The thermal expansion is increased by rapid firing and by increased Na_2O content of the feldspar.

Acknowledgements

Acknowledgment of assistance is made to E. E. Pressler and A. C. Harrison for physical tests and V. C. Swicker and R. B. Rudy for chemical analyses.

AN AUTOMATIC DEVICE FOR TAKING MOTION PICTURES AT REGULAR TIME INTERVALS[1]

By F. G. Keenen, G. W. Bennett, and Wesley G. France

ABSTRACT

An automatic apparatus for taking single photographic exposures at regular intervals of time over periods of from 12 to 36 hours was constructed. It consists of a large air thermostat and three mechanical units: (1) the thermal regulator, (2) the illuminating and optical system, and (3) the automatic mechanism controlling the camera and illuminating system. A detailed description of the construction and operation of the apparatus is given.

Work, involving a moving picture record of the growth of macroscopic individual crystals, now being carried out in this laboratory necessitated the construction of an apparatus for taking single exposures at regular intervals of time over periods of from 12 to 36 hours. Since the apparatus when suitably modified, is capable of very general use, it is believed advisable to describe the mechanism fully. It is here described as used in the crystal study mentioned. However, among other problems of special interest to ceramics in which the apparatus is being used are the microscopic and ultramicroscopic investigations of (1) relation of colloidal content and plasticity in clays, (2) flocculation and deflocculation of clays, and (3) electrical migration of clay suspensions.

The apparatus consists of a large air thermostat and three mechanical units: (1) the thermal regulator, (2) the illuminating and optical system, and (3) the automatic mechanism controlling the camera and illuminating system.

The thermostat which contains the thermal and optical units, is a box 3 by 6 by 6 feet, made of "Compo-board" on a wood frame, covered with du Pont "Frabricoid" and equipped with two sliding observation windows which may be removed when access to the thermostat is desired. Temperature variations do not exceed $\pm 0.1°$ (at 30.0°C), and under favorable circumstances not over $\pm 0.05°$, over 24-hour periods.

A shelf bearing the optical unit divides the thermostat in two parts. Beneath the shelf is the thermal unit. Two liters of toluene contained in a large U-shaped glass tube (*A*, Fig. 1), nine feet long, by its expansion and contraction causes mercury to make and break an electrical circuit. This mercury makes and breaks contact through a battery of six dry cells, operates a relay (*B*) which in turn makes and breaks contact from the 110 volt a. c. line. The temperature is maintained by a standard Mazda 250 watt, 110 volt heater lamp (*C*). A water cooling coil of copper tubing (*D*) serves to equalize temperatures, while a small fan (*E*) provides thorough air circulation.

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. Received January 19, 1927.

The illuminating and optical unit is made up as follows: Light from a Bausch and Lomb microscope lamp (*F*) equipped with a 108 watt lamp, passes through the crystallization chamber (*G*), then through a projection lens (*H*) (Bausch and Lomb 6 E.F.) and is reflected at right angles by a plane mirror (*I*). A telephoto lens (*J*) (Dallmeyer, London, $F=4$ inches) directs the beam into a binocular eyepiece (*K*) provided with 5 mm lenses. One ocular of this eyepiece focuses directly on the film in a Bell and Howell automatic spring driven motion picture camera (*L*) from which the lens is removed. This type of camera uses 16 mm kodak safety film and is set in action by simply depressing a small button which releases the motor that drives the film and operates the shutter. The action continues as long as the release

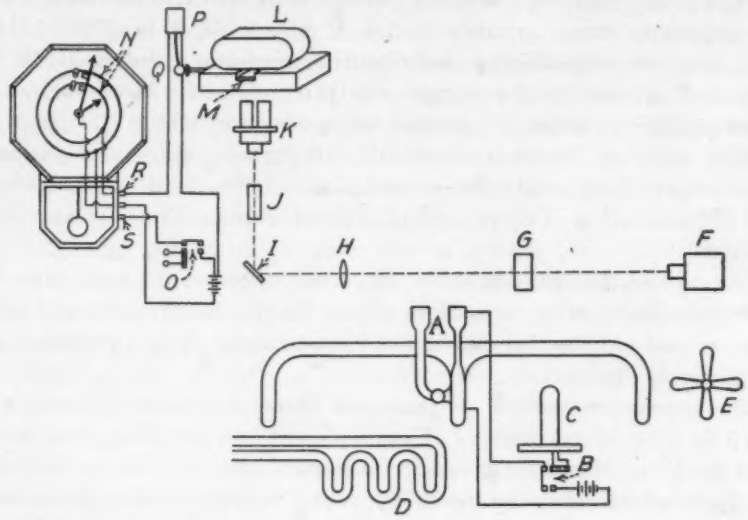

FIG. 1.

button is depressed. The other ocular focuses on a ground glass plate (*M*) which is at exactly the same level as the film in the camera. The crystal is thus kept in focus at all times without disturbing the camera. Focusing is done entirely by adjusting the projection lens which is provided with a screw for this purpose.

The automatic mechanism which is outside the thermostat is controlled by a specially modified eight-day clock. Beneath the face of the clock are two concentric brass rings (*N*) insulated from each other and from the clock face, each of which is wired to a corresponding binding post on the outside of the clock cabinet. Two concentric circles of holes lined up radially at five minute intervals, in the outer edge of the face of the clock permit removable brass plugs, insulated from the

clock face to be screwed into these brass rings. A silver minute hand bears at right angles to its end two strips of spring bronze, the under sides of which are covered with a tough, fibrous, insulating sheeting. This insulating material reaches to within a few millimeters of the ends of the bronze strips, and is slightly shorter on one of them. The minute hand makes good electrical contact with the works of the clock which are wired to a third external binding post. The minute hand after passing over the brass plugs causes the bronze strips to make contact with them. This hand is high enough to pass over the plugs without itself touching them and the hour hand is cut short so as not to interfere with the movement of the bronze strips.

Two circuits pass through the clock by means of the common binding post: one to a relay, and one to a single stroke bell mechanism. The strip having the longer metallic surface makes contact with its corresponding plug before the second strip makes contact. The first circuit closed, operates the relay (*O*) by means of a battery of six day cells. When the relay closes, the 110 volt a. c. line passes through the transformer which operates the Bausch and Lomb illuminating lamp. Shortly after this lamp has reached its maximum intensity, the second shorter bronze strip makes contact. The same battery of dry cells used on the thermal regulator operates a single stroke bell mechanism (*P*) from which the gong has been removed. The clapper (*Q*) of this bell communicates its thrust to a rod which rests against the camera release button. Five seconds later the minute hand has carried the bronze strips past the plugs and both circuits are broken. The bell clapper has a slight "kick" past its resting position when the current is on, and it is this kick which, when the communicating rod is of just the right length, makes the taking of a single exposure possible by only momentarily depressing the release button. If, however, it is desired to make two or three exposures, the rod is lengthened a little thereby increasing the time the release button is depressed. Of course, it is also possible to take the pictures as long as the current passes through the bell mechanism, by making the rod still longer. The removable plugs permit variations in the time interval between single exposures of from 5 to 30 minutes and one hour. By placing strips on the hour hand and adding another pair of concentric rings, other time intervals could be had.

The use of a clock to operate the automatic mechanism was resorted to after previous experiments had proved that two other devices were unsuitable. The first, a motor driven commutator made contacts for too great a period of time. The second employed an endless tape of standard width motion picture film driven by a motor reducing gear and cog mechanism over revolving spools.

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A NEW HIGH TEMPERATURE FURNACE CONTROLLER[1]

By F. H. Norton[2]

ABSTRACT

The need for accurate control of an oil-fired furnace operated at a temperature above the range of platinum thermocouples led to the development of a new type controller. Disadvantages of ordinary types of controllers are discussed. The mounting of the radiation pyrometer used is described. Full details of the construction and operating principles of the controller are given. Results obtained are far better than with most careful hand control.

Introduction

The occasion arose for controlling the temperature of a furnace, fired with oil, up to a temperature above the useful range of platinum thermocouples and with a variation of not more than $\pm 20°F$. For this purpose a type of controller was developed which has a number of novel features to insure its satisfactory operation under the exacting conditions stated above. It was believed that a description of such a device would be of general interest.

Nearly all temperature controllers operate on the on-and-off principle; that is, a fixed portion of the heat supply is turned on or off whenever the temperature is below or above the desired value. This system has the disadvantage of not giving at the same time a close control and compensation for relatively large changes in heat absorption. Another disadvantage of the on-and-off type is the difficulty of using it with oil burners where sudden changes in the amount of oil supplied cause inefficient combustion.

For these reasons a controller was used having means for gradually changing the oil supply, to maintain the temperature within the given limits even while there were changes in kiln load.

Temperature Measurement

In order to control the kiln the first essential is an accurate record of the temperature. The temperature is extremely high for a combustion furnace, and the only available recording instrument in this range is the radiation pyrometer.

The radiation pyrometer consists of one or more minute thermocouples so placed that an image of the interior of the kiln is focused on them by a lens or mirror. The electromotive force produced by the couples depends on the temperature of the furnace.

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[1] Received January 24, 1927.

[2] Babcock and Wilcox Fellow, Division of Industrial Coöperation and Research, Massachusetts Institute of Technology.

It is extremely important to have a minimum time lag between a temperature change in the kiln and the corresponding change on the record. Therefore no protecting tube can be used even if one which would stand the high temperature could be found. The pyrometer also should have a very small time-lag. An instrument of a type having two very light couples mounted in a vacuum tube was found to respond with only a few seconds lag.

The mounting of the pyrometer presents many difficulties, for it must be exposed directly to the interior of the kiln through an opening not less than 3 inches in diameter at a distance of about 3 feet from the instrument. Moreover there must be no possibility of smoke from the kiln settling on the pyrometer lens as the absorption caused by a very thin coating will make a large error in the observation. In addition the pyrometer must be kept cool; even when due to high pressure in the kiln, there is a tendency to leakage outward.

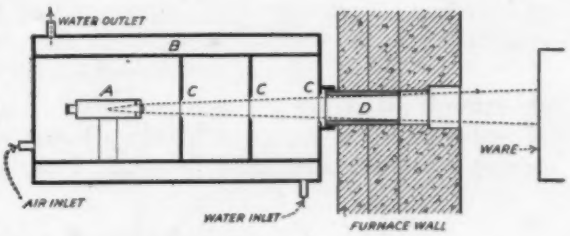

FIG. 1.—Pyrometer mounting.

After a great deal of experimenting the holder shown in Fig. 1 was evolved and on prolonged trial has proved to be entirely satisfactory. The radiation pyrometer, *A*, is mounted in the water-cooled jacket, *B*, and protected from stray radiation by a series of diaphragms, *C*. A refractory tube, *D*, sealed into the jacket extends into the furnace wall. In order to prevent any smoke or hot gases reaching the pyrometer, a small amount of air is forced into the jacket in order to have a slight flow from the casing into the furnace at all times.

The Controller

The controlling mechanism consisted of a standard recording potentiometer with special contacts. The potentiometer was selected because of its power for moving the contacts and its precision.

The Valve Operator

The controlling valve on the oil line was a standard spring-loaded reducing valve. The pressure adjusting screw on top of the valve was connected through a double worm reduction gear (100,000 to 1) to a 1/10 h.p. motor. This motor was a series a.c. type selected in

order to simplify reversing as shown later, and to keep the starting current at a low value. With this arrangement relays are eliminated.

The Control Circuit

The control circuit is shown in Fig. 2. The cams *A*, *B*, *C*, and *D* are mounted on the disk, *V*, which is operated by the potentiometer, that is, the position of the cams is determined by the kiln temperature. When the temperature is too high the cams *A* and *B* close contacts *E* and *G*. This closes the oil valve by operating motor *K*. When the temperature is too low the potentiometer causes a rotation of disk *V* in the opposite direction which opens contacts *G* and *E* and closes *H* and *F*. This operates the motor in the reverse direction, which opens the valve. The contacts *E* and *F* are connected respectively to the field of the motor through resistance *I* and *J*. When *F* is closed the motor operates with the field coil *M*, giving a closing direction; while *E*, when closed, connects to coil, *L*, giving a field of opposite polarity and operates the motor in a reverse direction. The resistances, *I* and *J*, are so adjusted as to give a slow speed to the motor when *E* or *F* are closed. If the temperature is more than a small amount from the normal point the cams *A* or *D* act, closing the contacts *G* or *H*, which short circuits the resistances, *I* and *J*, and drives the motor at high speed. We thus have an arrangement for changing the oil supply in the proper direction to correct any error in temperature; and this change occurs rapidly when the temperature is far from normal and slowly when it is close to the balancing point.

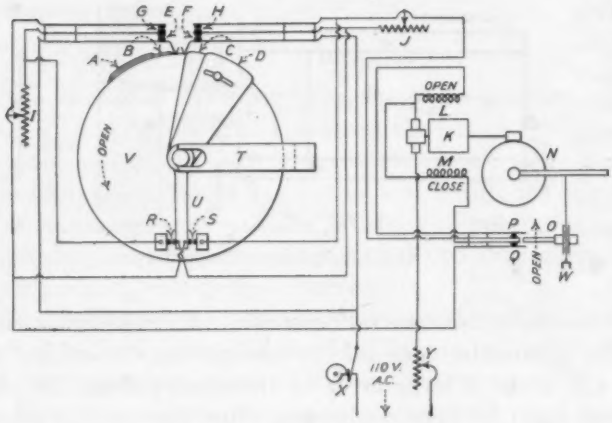

FIG. 2.—Control circuit.

This arrangement alone does not correct a temperature variation rapidly enough to prevent hunting above and below the normal. Therefore the contacts, *R* and *S*, are used to cut out the slow speed resistances, *I* and *J*, when the temperature is moving away from the balancing point. The arm *U*, is held lightly by the spring, *T*, so that

contact, *R*, is closed when the temperature is falling. This has the same effect as closing *H*, that is, running the controller motor at high speed. In this way we can so connect the motor, that it runs slowly when near to and approaching the balancing point, but runs at high speed at all other times.

Even with the best adapted system there is some lag between the time the controller acts and the corresponding temperature response, so the contact, *X*, is placed in the circuit. This is operated periodically by a cam which closes at frequent regular periods, for example for fifteen seconds every minute. This allows a corrective change in the oil supply to take effect before the next correction is made.

The controller motor, *K*, drives the reducing valve, *W*, through the reduction gear, *N*. The arm, *O*, may be adjusted on the stem so that it operates the limit contacts, *P* and *Q*, thus preventing too great a change in oil pressure.

Adjustments

The best operation with a given kiln or furnace can only be obtained by the careful and systematic adjustment of the many variables in the circuit. The adjustment of the high speed rheostat, *Y*, and the low speed rheostats, *I* and *J*, is very important and depends on the sensitivity of the control valve and the quickness of response to control changes. The contact, *X*, should be adjusted in relation to the time lag in the temperature measuring circuit.

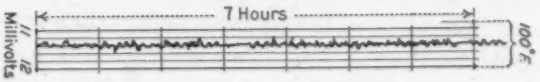

FIG. 3.—Automatic temperature control. Record on tunnel kiln.

The adjustment of the cams, *A*, *B*, *C*, and *D* must be made by trial to cut the hunting to a minimum and at the same time pick up the temperature rapidly after a burner change or other shut down. The contacts *R* and *S* should be set as closely as possible and still function.

The contacts, *P* and *Q*, should be set fairly closely to the running temperature so that if the controller ceased to function the oil supply could not be changed sufficiently to do any damage.

Actual Results

In Fig. 3 is shown the control record taken from a tunnel kiln under automatic control. The chart is in millivolts and is therefore not uniform in regard to temperature but gives an open scale at the upper end. The average variation is approximately ± 0.1 millivolt which is a temperature variation of only ± 10°F. The occasional large

variations are about twice this value. This control is far better than the most careful hand control.

This type of controller has also been used on small laboratory furnaces fired with gas. The controller was connected to bare base-metal couples, protected platinum couples and to radiation pyrometers. The base metal couples and the radiation pyrometer gave equally good results, holding the variation within $\pm 0.3\%$ of the temperature reading. The protected couple, due to the lag produced a slight hunting of 1%, but it was rather rapid and of equal oscillations, so that objects in the furnace would be held closely to a mean temperature.

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STUDIES IN POROSITY AND PERMEABILITY CHARACTERISTICS OF POROUS BODIES[1]

By W. L. Howe and C. J. Hudson

ABSTRACT

Definitions are given of porosity, permeability, and weight per unit volume. It is shown that these three terms are not synonymous, and that a change of permeability is not necessarily accompanied by a change in porosity.

Introduction

Porosity, permeability, and weight per unit volume are physical properties which are recognized as important in the use of grinding wheels, air diffusers, and filtering media in the chemical engineering field and in studying the characteristics of cement, stone, and so forth. Unfortunately porosity and permeability are often confused and porosity and apparent density are often incorrectly used interchangeably. It is the object of this paper to set forth certain data which it is hoped will help to clarify the situation and at the same time present certain interesting facts.

These data were obtained while studying porous plates made up of aluminous abrasive grain and a clay bond fired to a glass at about cone 12: a product which is finding considerable use in sanitary engineering. These plates are most commonly rectangular, 12 by 12 by 1 inches, and are used in the bottom of activated sludge sewage disposal tanks to permit air to be forced through the sewage, thus promoting bacterial growth and purification. For this type of work, plates are usually ordered with certain permeability ratings which must be met within narrow limits; for example, plates may be required to pass between 13.0 and 16.0 cubic feet of air at 70°F per minute per square foot of plate area under a pressure of two inches of water.

When porous plates are used as filtering media it is important to know the rates of flow of the liquids or gases to be passed through them and how the rates may be controlled by changing the permeability of the plates.

In the grinding industry the porosity of the grinding wheel plays an important part in its action. One wheel may be so open or porous that the abrasive grains are readily torn out and excessive wear of the wheel results, or in other terms, the wheel is too soft. A second wheel, less porous than the first, may generate excessive heat because the wheel tends to rub the work instead of freely cutting it when pressure is built up between the work and the wheel.

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[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (Terra Cotta Division.) Received February 7, 1927.

Definitions

Before going into further detail it will be well to define the properties which are to be discussed.

Weight per unit volume is the value obtained when the weight of a porous specimen is mathematically divided by the bulk volume. It is not the true density because of the volume of the pores included in the measurement.

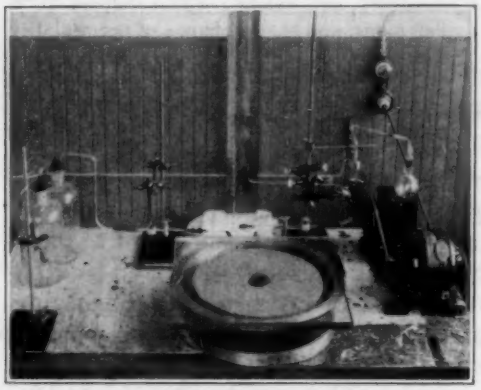

FIG. 1.—Air expansion porosimeter.

Apparent porosity is expressed as the percentage of the volume occupied by the pores based on the total bulk volume. Usually this value is apparent because of the difficulty in measuring the entire volume of the pores, although the air porosimeter designed by Washburn and Bunting gives values which are very close to the real porosity value for most materials.

Permeability is expressed as the quantity of air flowing through an article of definite area and thickness per unit of time when tested under an arbitrary constant pressure difference.

The porosity *apparatus* used was of the air expansion type which has been adapted to many uses by various investigators and widely discussed in this *Journal*. It is shown in Fig. 1 adapted to the determination of porosities of grinding wheels.

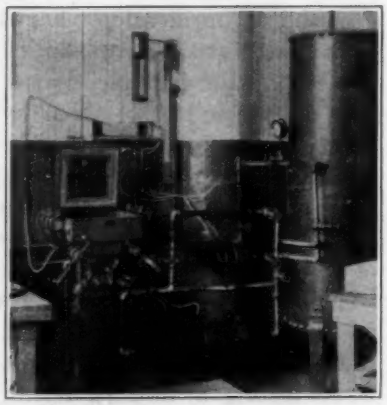

FIG. 2.—Apparatus for the determination of permeability of porous plates.

Figure 2 shows a photograph of the apparatus used for the determination of permeabilities. It consists essentially of a large air tank which absorbs the surges of air pressure from the compressors, three standard orifices connected to the proper gages, and the plate holder. Three orifices are provided in order to give air flow capacity enough to measure permeabilities over a large range. Only one, of course, is used at a time.

Figure 3 is a sketch showing the principle of the permeability apparatus. Air is permitted to pass from the pressure equalizing tank through the standard orifice or flow meter, where it is measured, to the plate box where a pressure is allowed to build up under the plate. At the moment when this pressure has built up to two inches of water above the atmospheric pressure the quantitative flow is read from a previously calibrated gage. An air seal is provided to prevent the air from flowing around the edges of the plate and to confine the part of the plate under test to a limited area.

Test Specimens

All the test specimens were made up in 12 by 12 by 1 inch size in order to determine the permeabilities. These were later cut up into smaller sizes to fit fairly snugly into special containers for the apparent porosity determinations.

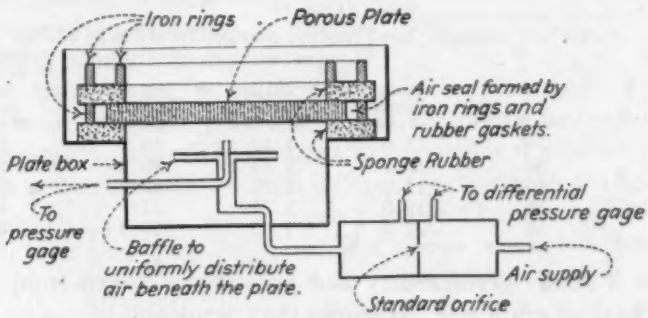

FIG. 3.—Permeability apparatus.

In order to test the effect of changes in grain size upon the physical properties under investigation, the following grain sizes were used:

Nominal Size	Av. diam. in inches
20	0.055
24	0.040
30	0.031
36	0.024
46	0.020
60	0.015
80	0.011

In all cases single grain sizes were used; mixtures of different grain sizes will lead to different results.

To test the effect of the amount of bond 30 grain size was used while changing the bond content from 5% to nearly 25%, keeping its composition the same.

Results

Following are the results of permeability, porosity, and weight per unit volume. In all cases the results are based on tests of two plates except No. 13 where only one was available. All plates were tested for permeability at a pressure difference of 2 inches of water.

TABLE I

Bond content constant; grain size changed from 20 to 80

Plate no.	Grain size	Bond content per cent	Wt. per cu. in. in ounces	Apparent porosity per cent	Permeability cu. ft. of air per min. per sq. ft. per 1 in. thick
2	80	15.0	1.18	40.4	8.6
4	60	15.0	1.22	37.4	17.6
5	46	15.0	1.24	36.0	25.1
6	36	15.0	1.25	35.8	38.0
7	30	15.0	1.25	35.2	53.4
8	24	15.0	1.25	36.2	64.3
9	20	15.0	1.29	34.4	73.6

TABLE II

Grain size constant; bond content changed from 5.6 to 22.7%

Plate no.	Grain size	Bond content per cent	Wt. per cu. in. in ounces	Apparent porosity per cent	Permeability cu. ft. of air per min. per sq. ft. per 1 in. thick
10	30	5.6	1.12	46.2	82.6
11	30	10.5	1.19	40.8	69.8
7	30	15.0	1.25	35.2	53.4
12	30	19.0	1.27	32.7	44.1
13	30	22.7	1.32	27.4	29.5

Figure 4 shows permeability and porosity, as taken from Table I, plotted against grain size. It shows that permeability can be changed from 73.6 to 8.6 cu. ft. of air by changing the grain size employed from 20 to 80, keeping everything else constant. The structure of the plates has been changed primarily in the size of the pores and indicates that permeability is very much dependent upon pore size; in general the larger the pores the higher will be the permeability rating.

Figure 4 also shows that the porosity values have not changed appreciably with grain size and shows that fluid flow is not necessarily related to porosity. One might conclude from a visual inspection of the 20 and 80 grit plates that the 80 grit plate is denser, less porous, and should have a higher weight per unit volume. Actually this is not so but only the permeability is affected by change in grain size.

It can be shown mathematically that the total vacant space in a container filled with spherical uniformly packed balls of a single diameter is constant regardless of the diameter of these balls. If the grains used in the manufacture of the plates had been spherical in shape then the porosity curve in Figure 4 would more nearly approach a horizontal

line; the smaller grain sizes tend to deviate more from equidimensionally shaped grains.

Figure 5 shows porosity and permeability plotted against percentage of bonding clay used; the curves show that both decrease with increasing percentages of bond, or in other words as the amount of clay increases, the product becomes more dense. The reason for greater denseness and lower permeability is that the spaces between the individual grains become smaller as they become filled with bond.

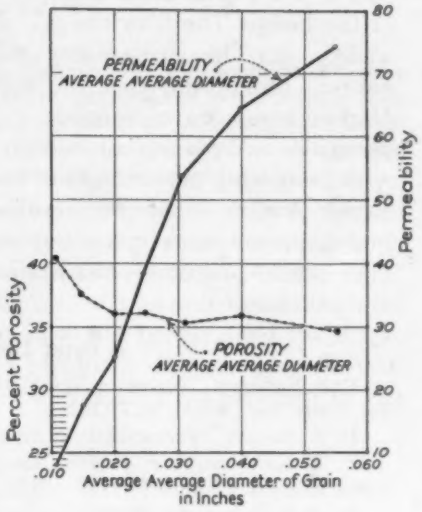

FIG. 4.

From Figs. 4 and 5 it may be concluded that permeability increases with grain size, or, what is the same thing, pore size; porosity is not necessarily dependent upon pore size. Increased bond content which in turn produces decreased pore size causes a decrease in both porosity and permeability. Therefore it ought to be possible to produce plates of about the same permeability with different porosities by changing both grain size and bond content.

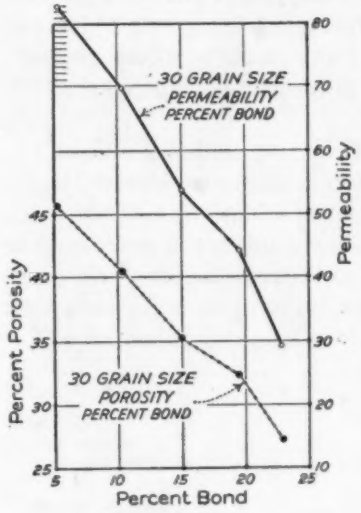

FIG. 5.

The above work has been done with single grain sizes. If a combination of grain sizes is used pore sizes can be varied over a wide range which will in turn cause a wide range of permeability values; it is possible to select these grain sizes so as to keep porosity constant. Together with a change in bond content, grain size, and combination of grain sizes, it is conceivable that porous bodies can be produced over a fairly wide range of permeability, porosity, and weight per unit volume.

Summary

In a vitrified porous body made of aluminous abrasive grains bonded with clay when other conditions are kept constant, the following facts were determined. (1) The permeability

can be changed over a wide range by the proper selection of the grit size of the grains without appreciably changing the apparent porosity of the body. The finer the grit size used, the lower will be the permeability. (2) The permeability can also be changed by varying the bond content but in this case the apparent porosity will also be changed. Higher bond contents result in producing bodies of lower apparent porosities and permeabilities. (3) The weight per unit volume increases with increasing percentages of bond, at least within the limits investigated. A more dense body results. (4) As finer grains are employed the body appears more dense but actually contains a greater number of finer pores, practically maintaining constant weight per unit volume and porosity.

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THE EFFECT OF FINE GRINDING ON AN INDURATED CLAY[1]

By Thomas C. Walker

ABSTRACT

Fine grinding develops certain desired physical properties of a clay that has become hard by the pressure of the overlying stratas and the heat produced by this pressure. The fineness of grind produces in direct proportion an increase in the plasticity, plastic tensile strength, and shrinkage, and a decrease in the absorption and porosity. An indurated clay can be made to produce required properties by the proper fineness of grinding.

The nonplastic clay in question is an indurated clay occurring in southern California and is covered with an overburden of sandstone. Under this clay lies a black clay similar in physical properties.

After grinding the clay and molding it into a form it was found that it lacked plasticity, so much so that it would hardly hold its shape. Even after several days of aging the plasticity did not develop. An attempt was then made to develop the plasticity by grinding to the following meshes:

All clay passing through { 10-mesh, 30-mesh, 100-mesh, 150-mesh

The 10-mesh clay was very short but plastic enough to retain its shape and to hold a small per cent of fairly fine grog. The 30-mesh developed enough plasticity so it could be used with grog in hand-molded ware and it was possible to run it through a die. The 100-mesh developed a very good plasticity of unusual quality, being rather tough, molding easily without cracks, and retaining its shape well. Little difference could be noticed in the working properties of the 150-mesh grind.

The fine grinding gives a direct increase in the water of plasticity, plastic tensile strength, and also drying shrinkage. When fired, the color remains about the same, except at cone 12 there was a tendency to blue stone in the fine grinding. According to the fineness of the clay there was a direct increase in the shrinkage and a decrease in the per cent absorption and the per cent porosity.

The following table gives the results of grinding.

	Raw Properties			
	10-mesh	30-mesh	100-mesh	150-mesh
Plasticity	Poor	Fair	Good	Very good
Plastic tensile strength in gms. per sq. in.	400	825	1900	1900
Water of plasticity	18.2	22.9	31.0	41.0
Drying shrinkage plastic	4.0	6.0	7.0	8.5
Drying shrinkage dry	4.17	6.4	7.5	9.2

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., February, 1927. (Refractories Division) Received February 8, 1927.

FIRED PROPERTIES

Cone No. 3

	10-mesh	30-mesh	100-mesh	150-mesh
Color	Light cream	Cream	Cream	Cream
Total shrinkage	10.0	12.5	13.5	17.0
Per cent absolute	10.5	10.6	11.2	9.2
Per cent porosity	21.9	22.3	23.1	18.7
Bulk specific gravity	2.080	2.100	2.050	2.100

Cone No. 6

	10-mesh	30-mesh	100-mesh	150-mesh
Color	Light cream	Cream	Cream	Cream
Total shrinkage	10.0	13.0	14.0	18.0
Per cent absolute	10.4	10.6	11.1	8.9
Per cent porosity	21.8	22.1	22.7	19.3
Bulk specific gravity	2.090	2.110	2.062	2.110

Cone No. 9

	10-mesh	30-mesh	100-mesh	150-mesh
Color	Light cream	Cream	Cream	Cream
Total shrinkage	11.0	14.0	16.5	20.0
Per cent absolute	9.1	9.3	6.1	2.9
Per cent porosity	19.7	20.6	13.9	6.8
Bulk specific gravity	2.160	2.210	2.290	2.360

Cone No. 12

	10-mesh	30-mesh	100-mesh	150-mesh
Color	Cream	Cream	Cream	Blue grey
Total shrinkage	11.5	14.5	17.0	20.5
Per cent absolute	9.0	8.1	4.1	1.0
Per cent porosity	19.5	17.8	10.3	2.6
Bulk specific gravity	2.170	2.220	2.470	2.510

The chemical analysis shows the clay to have the following composition:

Combined water	11.80
Alumina	37.92
Silica	45.30
Iron	3.48
Titanium	0.94
Lime	0.60
Magnesia	0.79
Combined alkalis	None
Total	100.83

Conclusion

This plastic clay that has become indurated by the application of moderate pressure may again be made plastic by breaking into small particles, the plasticity varying according to the number of particles. If the indurated mass is broken up to the fineness of the original clay then the indurated clay will have the same properties of the original. If a certain physical property is desired, it may be produced by grinding the indurated mass to a fineness that will give the desired result.

BOX 169
ALBERHILL, CALIF.

ENAMEL SYMPOSIUM[1]

ABSTRACT

I. The effect of manganese dioxide on the physical properties of ground coat enamels is: (1) to give a good gloss; (2) to give a harder enamel; (3) to reduce the coefficient of expansion of the glass in which it is used; (4) when used with cobalt a uniform color desirable in stove work is obtained; (5) no difference in the adhesion of the ground coat between enamels using manganese, cobalt, or combinations of dioxides is apparent; (6) no effect on chipping is apparent; (7) while not absolutely essential in ground coats it is very desirable for use from an economy stand point. II. A theory of ground coat adherence based on the fact that part of the steel is oxidized to iron oxide which is partly absorbed by the fused enamel and into which some of the enamel penetrates is set forth, and an explanation given of various effects obtained. III. Most of the things which should be done to maintain control in making and firing of ground coats for sheet steel are emphasized. IV. The method of control for application of ground coat enamel by weighing the amount of dry enamel on a sheet of metal of known area is described. This is used to maintain a uniform consistency of the enamel. Other essential features which have in the past caused trouble to many enamelers are mentioned.

Standardizing Shop Practices Relative to Making and Application of Steel Ground Coat Enamels. I.

By F. G. Jaeger

The Committee on Standards of the Enamel Division has done very creditable work in sending out questionnaires on making and firing sheet steel ground coat enamels to the members at different times. It has received comparatively few replies or, as the Report shows, only eighteen out of about 125 enamel plants solicited. This seems to indicate that the members are not wholeheartedly interested in a subject which should be of vital interest to every member of the Enamel Division.

Many of our members in their daily work encounter trouble and, when the nature of their trouble is with the ground coat, after having been fired on the steel, realize that high grade work is almost impossible on the imperfect ware, whether from under- or overfiring, poor cleaning, from enamels not suitable for the work to be done, or from other possible causes.

The Division members should be urged to realize the scope and importance of the work done by the Committee on Standards on factory control tests in the various operations taking place in all enamel shops and to invite discussions on the most important step in the work, *i.e.*, the successful application and firing of ground coat enamel.

The St. Louis District Enamelers Club has had a round table discussion on various subjects and much good has come from members' statements as to their own methods of handling the work. Most of us

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (Enamel Division.)

do not follow the various methods outlined on ground coat compositions, smelting practices, various control tests for fineness and setup. All of these vital subjects have been mentioned in the Report of the Committee on Standards and in the questionnaire to the 125 shops. If we would follow these many suggestions we should not hear of much ground coat trouble. The members who take part in this discussion should state just what is the cause of losses that sometimes mean disaster to owners of shops. It is also hoped that the discussion will bring out just what was done by the members to overcome their difficulties and also whether or not the result has been an effort to standardize on practices.

Bryan A. Rice has compiled from publications of the AMERICAN CERAMIC SOCIETY a list of papers[1] on various subjects covering all the operations in connection with enameling on sheet steel.

To bring out discussion on the subject in hand, just how many of the members present have read and carefully studied the paper "A Method of Control for Dipping Flat Ware"?[2]

How many members are using test No. 8 as outlined by the Committee on Standards, consisting of weighing a piece of steel before and after being dipped in the ground coat to determine the amount of enamel the difference in weight shows?

How many members carefully check pyrometer charts to find out if the ground coat has been fired at proper temperatures and consult production sheets to check time of firing of each heat of ware?

These mention only a few of the items, which if neglected are responsible for poor ware, losses, and grief of all kinds.

Harry Grospoeller, a St. Louis enameler, calls attention to the fact that the firing of a ground coat which has been quickly dried in a drier is much more easily controlled than one which has been dried slowly in the open air, temperatures being equal. This is probably accounted for by the fact that in the slow drying, iron oxide is formed, while in the quick drying, the oxide is not formed. Another paper by F. S. Markert, a St. Louis Enameler's Club member, "The Function of Manganese Dioxide in Ground Coat Enamels" will throw light on this subject we hope, and will cause discussion.

The Function of Manganese Dioxide in Ground Coat Enamels

In this paper I shall give a general idea of the functions of manganese dioxide in ground enamels as concluded from experiences in the use of it in our plant and what little I could find in enamel literature.

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[1] "Report of Enamel Division Committee on Standards and Bibliography," *Bull. Amer. Ceram. Soc.*, **5**, 234–51 (1926).

[2] R. R. Fusselbaugh and B. T. Sweely, *Jour. Amer. Ceram. Soc.*, **8** [5], 303–306 (1925).

Manganese, the metal, is used in the enamel industry entirely in the form of manganese dioxide or black oxide of manganese. It occurs in nature as pyrolusite, the purest grade of which is found in the Caucasian Mountains and will analyze over 85% pure manganese dioxide. Its chief impurity is iron oxide. The manganese dioxide used in our work is generally imported from that district in Russia.

The average amount of manganese dioxide generally used in ground coat enamels, as found by a comparison of various formulas, varies between ½% to 3% of the raw batch weight. Its chief function is that of a coloring agent. It is used to replace the much more expensive metal oxides, cobalt, nickel, and copper.

Manganese dioxide when used alone in a ground enamel varies in color from a drab green to a violet color. The intensity of the color varies, within limits, with the amount of manganese dioxide used. Such enamel may be used in the manufacture of hollow ware, in which case the color or appearance is not important as the entire piece is enameled with subsequent castings. In stove work where the appearance must be considered, cobalt oxide or other oxides are generally used with it as a darker and much more uniform and neater appearance is thus obtained; also the colors of enamels using manganese dioxide alone vary according to the amount of borax, bone ash, soda ash, etc., used in the enamel.

As noted from the borax bead test, in an oxidizing flame, the borax and phosphorous beads will become violet and the soda-ash bead will become green. Thus, it is only natural to conclude that the colors obtained in ground coat enameling by the use of manganese dioxide have bearing on the bead test. It must, of course, be borne in mind that these colors may be either hidden or intensified by the presence of other metals or oxides which will impart color to the glass.

Manganese dioxide is a powerful oxidizing agent when heated to 570°C (1058°F) or higher. It loses one-half molecule of oxygen passing from the form of MnO_2 to MnO_3. Chemically, manganese oxides are basic in nature thus tending to unite with the acid constituents of the enamel such as silicates and borates.

The effect of manganese dioxide on the physical properties of the enamel is as follows:

1. It gives a good gloss to the enamel.
2. It gives a harder enamel. Enamels high in manganese dioxide may be fired much harder with less danger of overfiring than those low in manganese dioxide and higher in cobalt oxide.
3. It tends to reduce the coefficient of expansion of the glass in which it is used.
4. It is not as neat appearing a color as cobalt but when used together with cobalt the color obtained is uniform and desirable in stove work.

5. There seems to be no difference in the adhesion of the ground coat to the steel between enamels using either manganese or cobalt alone or combinations of these two with other dioxides.

6. It has no apparent effect on chipping.

Some ideas of the amounts used in a practical formula are:

Per cent	Per cent	Per cent
½ cobalt oxide	1½ manganese dioxide	¾ stynium
¾ " "	2¼ " "	.....
1½ " "	.....	.....
.....	3½ " "	.....

In our plant all of these variations have been used at different times and the color and appearance of the ground coat varied but little.

Although manganese dioxide is not absolutely essential on ground coats, it is very desirable to use from an economy standpoint. It is not desirable to substitute entirely for cobalt, nickel, and other oxides. These can be partially substituted. The price of manganese dioxide is approximately six to ten cents per pound, while cobalt is over two dollars per pound, and nickel oxide is around fifty cents per pound. Thus it can easily be seen that any substitution of manganese for these oxides is quite a saving.

SUPERIOR ENAMEL PRODUCTS COMPANY
ST. LOUIS, MO.

Making and Firing of Sheet Steel Ground Coats. II.

BY R. D. COOKE

In the paper entitled "The Effect of Furnace Atmosphere on the Firing of Enamel"[1] it was shown that during a certain part of the period when the ground coat or one coat gray was in the furnace there was an absorption of oxygen by the steel. This took place from the time the steel was hot enough to oxidize until the time the enamel was soft enough to exclude the air from further action on the metal. It was shown that with reduced oxygen content of the air or reduced supply of fresh air the enamel assumed a peculiar ruffled appearance during cooling and failed to adhere well to the steel. It was also shown that when fired in an atmosphere devoid of oxygen, such as nitrogen, there was no adherence whatever between the steel and the enamel. The latter either rolled up in drops which fell off on cooling or ruffled and peeled off as soon as the piece was cool.

The following theory of ground coat adherence is based on the above facts. The first thing that happens when the ware enters the furnace is a general heating up of the entire system, steel and enamel.

[1] R. D. Cooke, *Jour. Amer. Ceram. Soc.*, **7** [4], 277–81 (1924).

Then, after a sufficient temperature has been reached, the surface of the steel begins to oxidize taking its oxygen from the air that filters through the rather coarse pores in the ground coat biscuit. A layer of iron oxide of more or less thickness is thus formed on the surface of the steel. The enamel then begins to fuse, shutting out further supply of oxygen. When the enamel is fully fused and up practically to the temperature of the furnace, it begins to exert its solvent action on the layer of oxide. The upper or outer surface of the oxide film is absorbed into the enamel, and some of the enamel penetrates into the inner surface. This diffusion process is shortly arrested by the withdrawal of the ware from the furnace and the final condition may be thought of as a system beginning with pure iron oxide at the surface of the steel and ending with "pure enamel" toward the outer surface. Between, there is a gradual decrease in concentration of oxide and an increase in concentration of enamel through a portion of the cross-section, like the shading off of one color into another in the rainbow.

Thus far we are dealing with facts which anyone may verify with the microscope if he cares to take the necessary pains in preparing specimens. It may be profitable to speculate as to what these things may mean in terms of coefficient of expansion. Steel is generally taken to have a linear coefficient of about 110×10^{-7} and most successful ground coats have been found to have coefficients of from 85 to 95×10^{-7}. Keeping in mind the picture of a cross-section consisting of a series of layers of gradually decreasing richness in oxide and increasing richness in enamel we see at once that there must also be some progressive change in coefficient of expansion.

I have been unable to find a figure for the expansion of pure iron oxide. From the Mayer and Havas tables the factor for Fe_2O_3 is 1.33. On this basis the expansion of 100% iron oxide would be 133×10^{-7} but of course these tables do not contemplate any such wide variation from the composition of glass and the figure is probably wrong. It is thought that the coefficient of expansion of Fe_3O_4 is very close to that of iron itself. Such being the case there would be a layer next to the steel having a coefficient of 110, a series of layers of progressively less expansion, and finally a relatively thick layer of enamel with a coefficient of 95 or whatever the case may be. Such a system is better able to compensate the strain between the steel and the enamel due to unequal contraction than if there were an abrupt change from coefficient 110 to 95.

There is now sufficient explanation for ruffling of the surface of ground coat during cooling when it is fired with insufficient oxygen. Assuming that there is such an abrupt change, the effect during cooling would be to put the enamel under compression since the steel contracts

faster than the enamel. While the enamel is still soft it wrinkles up to accommodate itself to the smaller area available. When the steel has oxidized properly, as when there is no deficiency of air, the progressive change just described has a cushioning effect and distributes the strain through a part of the thickness of the coating instead of concentrating it at one place.

There is also in these considerations a reasonable criterion for determining whether a certain metal can be enameled. If the metal is one which oxidizes when heated in the air, it is probable that it can be enameled, provided, of course, that its melting point is sufficiently high.

BENJAMIN ELECTRIC MFG. COMPANY
DES PLAINES, ILLINOIS

Emphasizing the Control of Methods Used in the Making and Firing of Ground Coats for Sheet Steel. III.

BY ROGER FELLOWS

Enameling troubles in most shops are due to carelessness in handling or neglect in controlling the various operations in the process of enameling. Oftentimes troubles occur in a shop and the cause is found and corrected, but nothing is done to prevent further occurrence of the same trouble. For instance, if there is difficulty with the ground coat fishscaling and it is discovered that the pickling acid is too weak, the acid is strengthened and probably the trouble disappears. The pickling acid is then tested every day for several weeks. If this test is neglected there is another siege of fishscaling which is again found to be due to the weakness of the acid. Thus it is through all of the steps in the making and application of enamels.

Most of us know what ought to be done to keep the various operations of our shops under control, but how many of us do it as we should? Some steps that we should pay most attention to in the making and firing of ground coats for sheet steel are discussed.

In the smelter room the raw materials that are used in the frit must be very carefully selected, analyzed, and tried out before being used. An analysis should be made and a test batch run of each new shipment of raw materials to make sure that the material is satisfactory. All raw materials should be stored in a clean, dry place. It is almost necessary to blend materials such as feldspar where there is most apt to be a variation.

The scales used in the smelter room as well as other places in the shop, should be cleaned thoroughly and checked up from time to time

to be sure that they are in proper condition. This may be easily neglected, but it is important.

The moisture contents of the raw materials should be determined and taken into consideration when weighing up the batch. Borax may lose some of its chemically combined water while other materials such as nitrate of soda and fluorspar may take up considerable moisture from the air. This moisture in the raw materials may oftentimes introduce considerable error in the compounding of the batch if care is not taken.

A mechanical mixer for the batch is far better than mixing by hand as it gives a much more uniform mix. This also decreases the time of smelting and results in a more uniform frit.

The spreading tools and stirring rods used in the smelting of the frit should be made of a metal that will not rust or scale from the high heat.

There are possibly advantages in blending two or more ground coat frits which are made from different formulas. We know that one frit made from blending two formulas does not give the same results as blending two frits made from two separate formulas. By blending frit with a high boric acid content with one of a high soda content in varying proportions one can probably regulate the ground coat so as to fit various types of ware better than can be done with one frit. It seems that the ground coat has a more open structure when made into two blended frits than when one frit alone is used. The blending of frits tends to stabilize the enamel in much the same way that the blending of feldspar does because if one frit is a little out of line the other one helps to equalize it.

In the smelting of the frit the time and temperature of each batch should be as near the same as possible in order to get uniform results. It is best to keep a record of the time at which each batch is put in and tapped and also the weight of the frit produced. If the frit is dried, any errors due to loading wet frit in the mills are done away with.

There are many things that should be watched in the milling of ground coat enamel. Of course the clay used in ground coats is a very important item as it must run very uniformly to aid its dipping and draining properties. Vallender clay seems to be a standard clay for this purpose, although some are getting good results by blending several domestic clays.

Several per cent of feldspar in the ground coat mill will aid in preventing the enamel burning off on the edges as well as in giving a more open structure to the enamel. Quartz may be used for the same purpose but it has a tendency to make the enamel more brittle. If too coarse a feldspar is used in the mill, little white specks can be noticed in the fired ground coat so that a feldspar no coarser than 140-mesh should be used.

We know that the amount of water used in the mills has a great deal to do with the fineness that the enamel will be milled, in a given time. So in order to get more uniform milling, the water should be measured accurately, preferably by a meter.

Using a revolution counter on the mills gives an accurate means of telling the length of time the mills have been run, which aids in getting uniform results. (But how many of you use them?)

The amount of stones kept in the mill also should be watched carefully. The mill should be kept at least one-half full at all times; the lining also should be inspected from time to time.

A screen test of the enamel before it is taken from the mill is advantageous and desirable. A test which is used with good results in some shops is as follows: A given weight (about 100 grams) of enamel from the mill is washed, first through a 60-mesh, then through a 200-mesh sieve, and the residue on the 200-mesh sieve is dried and weighed. The weight of the residue should be about the same from each mill, the amount of which is in proportion to the fineness that the enamel is milled. It is of course very important that the water is accurately measured when loading the mills in order to get uniform results with this test.

In the application of ground coat the cleaning and pickling of the steel plays such an important part and is so often the source of trouble that it might be well to emphasize the means of controlling the pickling process.

The cleaning and pickling solutions can be easily kept at certain concentrations by means of testing pills or titration. The solutions ought to be tested daily. (Do you do it?) We have found it advantageous to change the neutralizer daily in order to have a clean solution as the final wash before the dipping operation. In this way the neutralizer is kept at the correct strength every day and it also prevents any danger of having the neutralizer too strong, which may cause setting up of the enamel in the dipping tanks. If it is thought best to keep the cleaning and neutralizing solutions boiling, be sure that they are kept boiling.

The enamel in the dipping tanks ought to be sieved at least once a day. Sometimes this is not done properly because of the time and labor it takes, but it can easily and quickly be done without thinning by using an air-vibrating sieve.

The amount of the enamel that should remain on the ware after dipping varies with the gage of the steel used and with the shape of the ware. Thus the thickness of the ground coat often has to be left to the judgment of the foreman or dipper. However, there are several ways by which the enamel may be tested which are very satisfac-

tory. One way which is being used with very good results in several shops is simply to weigh a given volume of the enamel. By keeping the weight the same they keep the enamel of about the right consistency. Probably the surest way of knowing whether the enamel is of the right thickness is to fire a couple of samples dipped at various times during the day. The use of setting up chemicals in the dipping tank should not be necessary as the enamel should be set up in the mill all right. By adding them in the dip tank it tends to increase the danger of varied results.

In the firing of ground coat the time and temperature should be watched. Poor ware will often result if the fire is raised and the ware is fired too fast. Sometimes troubles may be corrected by hanging the ware or by placing it on special tools.

A good inspection of the ground coat will save much trouble later on. All underfired pieces should be refired and the overfired pieces redipped.

In summarizing this paper, we suggest that you analyze your own management of your shop to see if you do the following things in controlling your ground coat:

Do you run your shop as it ought to be run?
Do you keep the mill room clean?
Do you look at the linings of your mills?
Do you keep your mills half full of pebbles?
Do you accurately measure the water that is put in your mills?
Do you run a screen test of each mill of enamel?
Do you test the pickling acid daily?
Do you sieve the enamel in the dip tank daily?
Do you watch the dippers?
Do you watch the temperature of the furnaces?
Or in other words,
Is your shop under control?

CHICAGO VITREOUS ENAMEL PRODUCTS COMPANY
1407 S. 55TH COURT
CICERO, ILLINOIS

Method of Control for Application of Ground Coat Enamel. IV.

BY A. JENNINGS

The proper application of the ground coat in enamel work is the most important part of all of the enameling processes, because it is the foundation upon which rests the success and efficiency of the rest of the enameling operation.

To emphasize the above statement, let me call your attention to the old saying that "a structure is no stronger than the foundation upon which it is built"—and so the foundation for enameling is even more

important than it is in a building operation because without the solid foundation coat of enamel you cannot get a proper second or finishing coat.

The first finishing coat may stand up but when the piece receives the third firing the foundation crumbles and the piece is spoiled. Therefore, the most important operation in enameling is to get a proper application of the ground coat.

The following will describe in concise form the method of applying the ground coat as it has been worked out in the shop of the Buck's Stove and Range Company of St. Louis, Mo. We have been securing most excellent results from this method which is known as Test No. 8 as set forth by the Committee on Standards.

The enamel is delivered from the enamel mill room to the enamel shop in tubs which are protected with covers to prevent any foreign substance getting into the enamel and further to keep the enamel from splashing out of the tub during the transportation from one position to another.

The enamel is poured through a 50-wire mesh strainer into a large tank of about 900 pounds capacity, and in this tank the ground coat is then very thoroughly mixed so as to get a uniform coat throughout.

A piece of steel made of No. 22 gage Armco iron containing two square feet is used for making the test. This is done by dipping this piece in the ground coat slush and hanging it up to drain. The test piece of steel has been very accurately weighed prior to the dipping operation and after the test piece has thoroughly drained it is placed on an accurately balanced scale and the weight of enamel on the test piece is obtained. This weight will vary, of course, with shop practice, some desiring a lighter and some a heavier coat for this purpose.

Should the test piece show that the enamel is too light as compared with the standard then it is necessary to add some heavy enamel to obtain the proper standard. If it should show that the coating is too heavy as compared with the standard it is necessary to add water to thin out the mixture to the proper consistency and then another test is made and weighed accurately as described above.

It is necessary that a new test be made after every change in order to obtain accurate results.

The addition of water to a tank of ground coat enamel requires exceptional care and must be done properly or serious trouble may result. The water added to the ground coat mixture must be thoroughly stirred so that there can be no part of the mixture which has more water than another part. Should the mixture not be thoroughly stirred the heavy enamel will be at the bottom and a light, thin enamel on top of the tank.

In addition to the above test of ground coat when the new batches are made, it is also advisable to make the regular test twice every day to see that no change has taken place in the enamel and that it has been kept thoroughly stirred. This will save many a lost piece if attended to regularly. These ground coat tests should not be left to a subordinate but should be the responsibility of the foreman of the shop.

The above method of setting the ground coat and getting it of uniform thickness has been of material assistance to us when spraying the black edge on the ground coat before the latter is fired. An even coat of ground enamel will take the black edge to a much better advantage than either a coat which is too light or too heavy.

We spray the black edge enamel on the ground coat before firing with about a forty-pound air pressure. This pressure is cut down from eighty pounds by a regulator at the spray booth and must be kept at a low pressure; otherwise the moisture in the black edge coat will force its way through the ground coat to the steel and blistering will follow. The result is that there is a fine, light spray of black enamel to cover the edge on the ground coat.

This black edge coat being kept very thin will prevent the cracking of the enamel of the cover coat after the second cover coat has been applied, whereas if the black edge coat is put on heavy the second cover coat will hairline and crack.

In firing the black edge where the pieces have flanges, the ware is set so that the edges do not come close to each other as this gives the ground and the black edge ware an opportunity to burn down. This would not occur were these edges close together. Where the edges are placed close together there is not a proper circulation of the heat and the extra black coat on top of the ground coat prevents the proper firing.

There is one piece which stove manufacturers in many shops have had extreme difficulty in finishing properly. This is the rolled edge top shelf on the gas stove. We find that by placing this rolled edge next to the wall of the muffle it helps materially in the firing of these pieces. The shape of this piece with its curved edge seems to make a pocket and the ground coat does not properly fire unless it is given the advantage of being placed next to the wall of the muffle where it gets possibly a little more heat than the rest of the piece.

THE BUCK'S STOVE AND RANGE COMPANY
ST. LOUIS, MO.

Discussion

E. P. POSTE[1]: The several papers composing the Symposium have been read with the work of the Standards Committee in mind and it is gratifying to note the appreciation for control standards manifest throughout.

Mr. Fellows' reference to the moisture content of enamel materials suggests two statements. Some materials tend to gain moisture under average storage conditions while others lose moisture. In connection with the first case dry storage is necessary and warm storage will do no harm, but with the other class warm storage may do harm. Borax is the chief example. If stored in a warm dry place it will lose moisture changing from $Na_2B_4O_7 \cdot 10H_2O$ towards $Na_2B_4O_7 \cdot 5H_2O$. In this case the introduction of the specified amount without correction will result in an excess of borax. Borax should be stored in a dry place but should not be heated. This point is brought out in view of the fact that at least one firm is storing its borax in a specially heated room. The other point is with regard to clays. It often happens that a clay as received will contain as much as 15% moisture and on air drying will come to around 3%. This difference unless corrected is enough to make a definite variation in the actual amount of clay introduced.

In addition to knowing the number of revolutions, it is essential that the speed of a mill be constant to produce uniform results. Slippage of belt or other causes of speed variation will affect the amount of grinding done in a given number of revolutions.

The importance of the angle of draining in the ground coat control test should not be overlooked. The Standards Committee will soon have a suggestion to offer on this point.

[1] Received April 23, 1927.

SOLUTION OF FUSED ALUMINOUS MATERIALS[1]

By. R. W. Ellison

ABSTRACT

A modification and combination of two fusion methods used in the decomposition and dissolving of fused aluminous materials preliminary to analysis is presented as giving none of the troubles encountered with either of the separate fusions.

Introduction

Considerable trouble is usually encountered in decomposing and dissolving fused aluminous materials preliminary to analysis. Especially is this true in the analysis of synthetic electrically fused silicates of the sillimanite and mullite series.

In the straight bisulphate fusion, when dissolving the melt in hydrochloric acid, an insoluble residue as high as 15% is very apt to be encountered, which is filtered off along with the silica; and when sulphuric acid is used as the dissolving medium, a residue as high or higher can be expected. The straight carbonate fusion results in an undecomposed residue as high as 10%, even after a two-hour fusion, and during the first stages of the fusion a violent "spitting" takes place, which is almost unavoidable.

The writer has had good success using a modification of the above methods.

Method

Place about 6 grams of potassium bisulphate in a platinum crucible and expel the water by gentle heating. Brush in .5 gram charge of the finely ground (200-mesh) material, and fuse until the melt is near-solid, taking care that nothing is lost by spattering or "boiling" over. Rotate the crucible while cooling, to bring the melt up on the sides of the crucible. After cooling, the cake can be detached from the crucblel by gently "working" the latter between the thumb and fingers uinti the cake loosens. Dissolve in the least possible quantity of water, add a few cubic centimeters of hydrochloric acid, filter through a 9 cm No. 41 Whatman (or similar fast filtering) paper into a porcelain casserole, and wash with as little hot water as possible. Ignite, and fuse residue with about 6 grams of sodium carbonate, and dissolve the melt in the original filtrate. Proceed with the silica and other determinations as usual.

The above procedure results in complete decomposition of the sample, and upon evaporating to dryness and baking, preliminary to filtering off of silica, gives a dry, and fairly open residue, from which the hydrochloric acid can be readily removed.

The Vitrefrax Company
Los Angeles, Calif.

[1] Received February 21, 1927.

MECHANICAL INTRODUCTION OF BARIUM TO CLAY BODIES[1]

By Marion W. Blair

ABSTRACT

Several methods of introducing barium to clay bodies are discussed. These include addition (1) in a wet dilute solution, (2) in a wet concentrated solution, (3) dry by sprinkling on to the raw clay in the car before grinding, (4) dry to the dry pan or crusher in proportion to the speed of the machine, (5) dry from a disk feeder applying the clay to the pug mill.

Introduction

The use of barium carbonate in clay bodies, for the reduction or elimination of scum, has become a very common practice in the manufacture of face brick and other clay bodies. The chemical reactions involved have been discussed before this Society and such discussions may be found in the *Bulletin*.[2] Information as to the best, most economical, and most convenient application seems not to be so generally distributed, but like many methods and shop practices in the manufacture of clay wares, in the introduction of small amounts of material such as manganese and barium, the best method seems to be a matter of individual judgment.

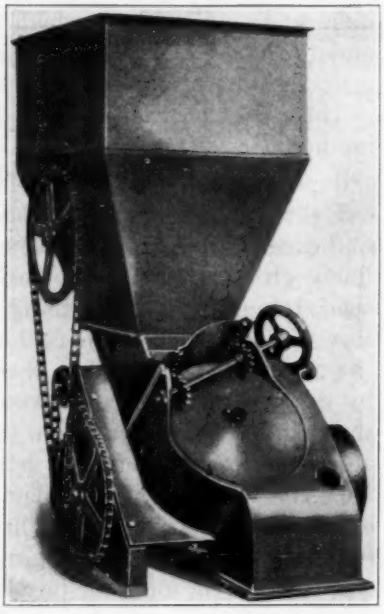

Fig. 1.

The careless or unnecessary use of an expensive chemical adds to production costs. In the use of barium, the amount can be reduced to a minimum by seeing that the ware is not subjected to sulphur fumes unnecessarily and that drying and water-smoking are not allowed to lag. However, if it is cheaper to use fifty cents worth of barium than it is to clean the clinker from a cooling kiln, the answer is obvious.

The amount of barium to be used per ton of clay can only be determined by experiment, mixing a known amount per ton and increasing it until the scum disappears; then

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (Heavy Clay Products Division.)

[2] See "A Descriptive Bibliography of Scumming and Efflorescence" by F. G. Jackson, *Bull. Amer. Ceram. Soc.*, **4** [8], 376 (1925).

cutting down the amount until it reappears and increasing slightly beyond a safety point. The amount varies from 2, 4, 6, up to 20 pounds per thousand brick.

Method of Adding

Wet Dilute Solution Barium carbonate is only slightly soluble in water and, if applied wet, it must be constantly agitated; otherwise it will settle to the bottom of the mixing tank. One method of wet application is to have two tanks from which the pugging water is taken. The amount of water required for a given weight of clay is determined and the proper amount of barium added. One tank is being filled and charged while the other is being emptied. The tank is provided with mechanical agitators run by motor or counter shaft. When one tank is emptied, the second tank is drawn from and the first refilled. This method is uncertain, as the amount of water required varies with the clay condition and, as the water used varies, so does the amount of the chemical which gets into the body, even assuming that the stirring is 100% efficient.

Wet Concentrated Solution Another method is to use a more concentrated solution by means of a throttle valve and a fly ball governor, driven from the measuring belt pulley. An amount is delivered proportionally to the travel of the clay column. This method is, of course, put out of balance by the amount of scrap that is returned to the pug mill and has the disadvantage also that the more concentrated solution must be carried in open troughs rather than in pipes, because the barium will settle out of the solution if carried any considerable distance.

A modification of this method is the use of a dry feeder which is nothing but a fertilizer feeder driven either from the measuring belt or the pug mill and discharging into a trough simultaneously with the pugging water.

Dry Another method is to sprinkle the proper amount on to the raw clay in the car, before it is dumped into the grinding machinery, be it crusher, dry pan, or pulverizer. This method lacks accuracy and has the disadvantage of treating all clay alike, even though some of it may be used for ware in which freedom from scum is not a matter for serious consideration. It is also a question of how thorough the mixture is, as undoubtedly the pulverized barium goes through the dry pan ahead of the main portion of the clay or shale.

A more accurate application is to feed the barium to the dry pan or crusher in proportion to the speed of the machine, the feeding conveyer or plate feeder, as the case may be. There is, of course, danger of feeding barium in a continuous amount and not feeding clay but this

is under control by the pan operator. Finally the feeder is so arranged as to run from a disk feeder applying clay to the pug mill and the barium is fed either onto the revolving disk and is scraped off with the clay, or it is discharged at approximately the same point.

There are several types of dry feeders upon the market, most of which have been developed in the milling business for the mixing and proportioning mixed grains, feeds, or other mill products requiring accurate proportions. Others are constructed like miniature pug mills with paddle blade. Still others are built like screw conveyers but with cut or ribbon flights.

2131 S. Center St.,
Terre Haute, Ind.

COMPARISON OF THE EXPENSES FOR OPERATING THREE DIFFERENT TYPES OF KILNS[1]

By Otto Kauffmann

ABSTRACT

A comparison made of a system of six round kilns, a sixteen chamber Mendheim gas kiln, and a tunnel car kiln system Saarau shows the tunnel car kiln to have the best figures concerning amount of fuel and time of firing, but less favorable with regard to wages and amount of broken saggers. There is also a difference in the quality of the tile.

The kilns in question are a system of six round kilns, which are connected by channels for the waste heat, a Mendheim gas kiln with sixteen chambers and a tunnel car kiln system Saarau. They fire the same kind of vitrified tile and the output of each system is nearly the same. The tunnel car kiln is generally used only for white tile and other light colors which need the same amount of heat.

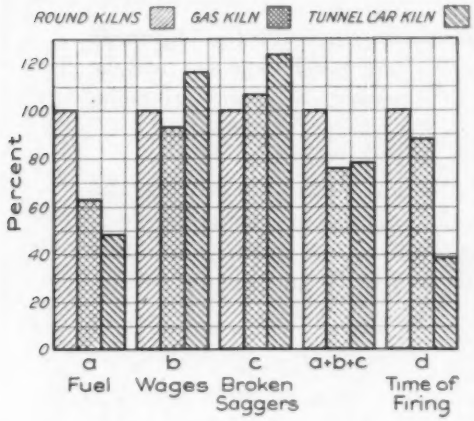

FIG. 1.

In Fig. 1 the figures concerning the six round kilns are used as equal to 100, to which the figures of the gas kiln and the tunnel car kiln are placed in comparison. The diagrams show (*a*) the amount of coal and coke, used for firing the same quantity of tile, (*b*) the wages spent for running the kilns and handling the tile, (*c*) the amount of broken saggers, ($a+b+c$) the expenses for fuel, wages and broken saggers, and (*d*) the number of hours necessary for firing the tile.

Although the tunnel car kiln has the best figures concerning the amount of fuel and time, the other systems are more favorable with regard to the wages and the amount of broken saggers.

Although the figures are based on a rather long period, they are not to be considered as unchangeable. They are merely meant as a suggestion for making similar comparisons in other plants.

Niedersedlitz, Germany

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[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (White Wares Division.) Received Feb. 4, 1927.

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Under Auspices of

The American Ceramic Society

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Arrive Glasgow.....May 28
In England.....May 30 to June 7
In Germany.....June 7 to June 14
In Czechoslovakia.....June 14 to June 20
At Milan, Italy.....June 23
In France.....June 24 to June 30

Extension of these trips will be arranged for those who will wish to go to other places and to spend a longer time abroad.

CERAMIC ABSTRACTS

Compiled by the

AMERICAN CERAMIC SOCIETY

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[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was obtained from *Chemical Abstracts* by coöperative agreement.

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Abrasives

Abrasives in Canada in 1925. DOMINION BUREAU OF STATISTICS. *Chem. and Ind.*, **46**, 243 (1927).—The "miscellaneous nonmetallic mineral products" industry in Canada had 35 plants in 1925 with an output value of $7,978,183. This includes 13 abrasive plants, 2 plants making graphite electrodes, 8 concerns making gypsum products, 11 mica-trimming shops, and 1 plant making foundry supplies. Production of artificial abrasives such as crude Carborundum, aloxite, fire sand, and fused alumina was valued at $5,186,802. Four plants in Ontario and one in Quebec made artificial abrasives, while 8 in Ontario manufacture grinding-wheels, sand-paper, etc. Capital employed in the industry amounted to $6,160,392; employees numbered 598 persons, salaries and wages totaled $853,458, and raw material cost $2,006,618. H.H.S.

Art

Low fire glazes using rutile. MYRTLE M. FRENCH AND CHAS. M. HARDER. *Jour. Amer. Ceram. Soc.*, **10** [4], 268–69 (1927).—A very fusible glaze containing rutile was fired at cones varying from 010 to 03. The fusibility was adjusted by introducing feldspar, and various colorants were added to control the color. The results were very interesting and varied—especially for a modeled or incised pattern.

Freeing the creative power of the individual through the making of pottery. MYRTLE M. FRENCH. *Design*, **28** [11], 201–203 (1927).—Helpful suggestions as to how to release creative instinct in students. Article urges use of symbolism in design as a vitalizing influence and gives examples. See also *Jour. Amer. Ceram. Soc.*, **9** [11], 779–82 (1926). E.B.H.

Old Blue Staffordshire in America. MALCOLM VAUGHAN. *International Studio*, **86**, 36–41 (1927).—This ware displayed American public buildings, events, and landscapes and its style was logical and sincere. At least 250 views are represented. E.B.H.

Recent accessions in the Near Eastern collection. M. S. DIMAND. *Bull. Met. Mus. Art*, **22** [3], 79–84 (1927).—Through the generosity of Edward C. Moore, Jr., the Museum has acquired from the Alphonse Kann Collection an interesting group of Near Eastern ceramics and metal work. Several of them are known to the scientific world from Pézard's publication on early Mohammedan pottery. There are examples of Gabry pottery, in its general characteristics belonging to group of pottery excavated at Hamadan and Zendjan in Persia. There is a bowl, probably of the 11th century, attributed to the Rhages school, which is of white clay with incised design. Bowl is glazed with turquoise blue which appears dark blue in incised parts. There is a 13th century bowl of the so-called "rice-grain" type with elaborate pierced decoration. Bowl is covered with transparent ivory-white glaze and streaks in blue. In this type we have Persian imitations of Chinese white porcelain which has always been appreciated by the Mohammedan world, but because of its high cost used only at courts of rulers. To the city of Rhages, destroyed by Mongols in 1221, are attributed ceramic wares with beautiful polychrome decoration of arabesques and figured scenes painted in rich colors over white glaze. This Rhages pottery is generally assigned to the 13th century and the Museum possesses many excellent specimens. Another example of overglaze decoration is done in brown-gold lustre. This art flourished in several places in Persia during 13th century. Besides Rhages, Veramin was an important center of ceramic art whence many dated lustred tiles have been obtained. The signs of the Zodiac, rare in ceramic art, form part of the decoration. This bowl is assigned to second half of 13th century and is of the Veramin type of lustered ware. Another important acquisition is the top of a richly decorated unglazed earthenware jar of a type of which only a few fragments are known. Most of this has been found near Mosul in Mesopotamia and was probably used for storing water and wine. A.A.A.

Leaded glass—clear, stained, and colored, is described. ANON. *Amer. Glass Rev.*, **46** [31], 35–36 (1927); reprinted from *Patton's Monthly*.—Leaded glass is a term for a method of treatment rather than any particular kind of glass, or, indeed, any particular metal as a setting for it. The purpose of this treatment is almost exclusively ornamental. The details of use thereof and beautiful effects obtainable are discussed. E.J.V.

Uranium in the ceramic industry. H. E. ROEMHILD. *Pottery Gaz.*, **52** [598], 619 (1927); reprinted from *Nat. Glass Budget*.—See also *Ceram. Abs.*, **6** [3], 117 (1927). E.J.V.

America's lack of original ceramic designs and also schools catering to the artistic fields in its clay working industries. F. H. RHEAD. *Pottery, Glass, and Brass Salesman*, **35** [7], 13 (1927).—An address presented at the AMERICAN CERAMIC SOCIETY meeting in Detroit. The need for artistic development in America is stressed. Ceramic art schools and courses that should be offered are discussed in considerable detail. Suggested lines of instruction are enumerated. E.J.V.

Alfred Mica Smith—obituary. ANON. *Chem. and Ind.*, **46**, 271–72 (1927).—Born in Scotland, 1844, he became lecturer at the School of Mines, Ballarat, Australia. He was a collector of rare china and presented his collection to the Ballarat Art Gallery. H.H.S.

Baroque art. H. S. SQUIRRELL. *Dublin Review*, **90**, 40–52 (1927).—Understanding and appreciation of Baroque are reawakening. S. sums up its spirit as color, symbolism, movement, optimism, and harmony between building and environment. H.H.S.

Color standards and color measuring. F. A. O. KRÜGER. *Farben-Ztg.*, **32,** 682–85 (1927).—The advantages of a new photometer, constructed by Carl Pulfrich of the Zeiss optical works, over Ostwald's photometer are explained. The former is said to give easier and more accurate measurements and to have a wider range. (*C. A.*)

Cement, Lime, and Plaster

Steam in limestone decomposition. VICTOR J. AZBE. *Cement and Eng. News,* **30** [7], 63–65 (1927).—A. finds no difference between steam and air atmosphere in the decomposition of lime and magnesia carbonates. He shows graphically the effect of air, CO_2, and steam upon the initial temperature and rate of decomposition. Steam made in the lime kiln wastes fuel and does not help decomposition. While steam may cause very high local temperature it also tends to reduce the average kiln temperatures. L.A.P.

A modern lime calcining furnace. H. HALBIG. *Fuels and Fur.*, **5** [4], 449–50, 459–60 (1927).—A description of the lime-burning furnace at the Government Nitrogen Works, in Chorzow, Germany. The refractoriness of the fire brick in the firing zone corresponds to Seger cones 32–33; in the preheating and cooling zone, to cone 30. Mechanically strong and well fired brick were desired, as they withstood best the abrasive action of the hard limestone. A.E.R.W.

Constant temperature-humidity box for the storage of cement test specimens. ANON. Bur. Stand., *Tech. News Bull.*, No. 119, 2 (1927).—The properties of cement and mortar test specimens are affected during the first 24 hours after making by the surrounding temperature and humidity. For this reason and to conform to the A.S.T.M. temperature requirements of $70° \pm 5°F$, a constant humidity and temperature storage box has been developed and put into successful operation at the Bureau. A detailed description of this apparatus is given. R.A.H.

Adhesion of mortar to sand-lime brick. ANON. Bur. Stand., *Tech. News Bull.*, No. 119, 2–3 (1927).—Tests on the effect of different percentages of water taken up by the bricks in a definite period were made on 6 makes of sand-lime brick. Bricks were classified according to percentage of water absorbed and tested for adhesion of mortar in 28 days. It was found that where the entire faces of both bricks are brought in contact with the mortar while it is sufficiently wet, greater adhesion is obtained with bricks of high than with low water absorption. R.A.H.

Density of concrete and the water-cement ratio. F. R. MCMILLAN. *Eng. News Rec.*, **98** [11], 445–47 (1927).—This paper presents a brief discussion, with a number of graphs, on the density and durability of concrete mixtures and how these properties are interrelated to the strength and water-cement ratio. M. shows that cement paste governs concrete density and density is a function of water content. R.A.H.

Investigation of the hydraulic compounds in iron and aluminous cements. ANON. *Mon. Sci.*, **16,** 97; *Rock Products,* **30** [1], 79–80 (1927).—The hydraulic compounds in these types of cements, according to a recent theory, are complex compounds of silica and lime in which the several atoms of silicon are bound together in the same molecule. The investigation carried out tends to disprove the existence of tricalcium silicate. The aluminum of the aluminum silicates reacts during clinkering to give rise to combinations of complex compounds of alumina, silica, and lime. Hydraulic properties of cements are said to be due to lime. Hydrated lime unites the cement ingredients, but is not a hydraulic bond because of its solubility. The hydraulic bonds consist of the insoluble or slightly soluble calcium combinations which are capable of hydrating or hydrolizing, and include certain silicates, the aluminates, some ferrites and titanites. For the manufacture of cements of these types, bauxite ores are generally used, and also residual sludges from plants using alumina and pyrite ash. Calcination is carried out at

temperatures ranging from 1000–1400°C, high iron contents using the lower temperatures. F.P.H.

Mineralogy of aluminous cement. ANON. *Zement*, **15**, 336–38 (1926); *Rock Products*, **30** [1], 80 (1927).—The mineralogical constitution of the aluminous cement clinker is shown to consist in most cases of gehlenite, monocalcium aluminate and, in part, of tricalcium penta-aluminate. Inasmuch as the mineralogical calculations which are made from the results obtained in analyzing the clinker, which in certain cases at least lead to the conclusion that the ratio in monocalcium aluminate between alumina and lime is 1:1.05–1.1, it would appear correct to say that the monocalcium aluminate or other mineral matters entering into the composition of the aluminous cement clinker contain a little lime in the state of a solid solution. Monocalcium aluminate, from the mineralogical standpoint, belongs to the rhombic crystalline family, characteristic of compounds of the type $RO \cdot R_2O_3$, just like the mineral which is found in nature and which is known as chrysoberyl. On examination of the pure monocalcium aluminate which is prepared synthetically, it is found that the angle of the optical axes has a value which is entirely different from that of the mineral which is found in the aluminous cement clinker, that is, 2V is equal to zero. On the other hand, the other optical characteristics of the synthetic and the natural product agree with one another. The fact that monocalcium aluminate, which is made by the fusion of the oxides of calcium and aluminum, has only a single axis is a subject of study which has been discussed at length. But the monocalcium aluminate which was made by Rankin and Wright, has, it appears, an axis angle which is equal to $2V = 36 \pm 4°$, while the mineral in silicate cement clinker has a greater angle ($2V = 56$). Hence this angle is subject to considerable variation and there is no definite value that can be assigned to it. F.P.H.

Determination of free lime in hydraulic cement. ANON. *Rock Products*, **30** [2], 98 (1927).—"Wet" methods of determining the free lime in hydraulic cements are not in general so satisfactory as "dry" methods, which is due to the fact that further hydration proceeds during the determinations and produces more free lime. Extraction with a 25% sugar solution yields useful and valuable information for set cements, and is a rapid method for testing the cement where only small quantities of materials are available. Passow's method (see *Zement*, **12**, 87 (1923)) in which ammonium carbonate is heated with the cement and forms calcium carbonate with the free lime, is not very satisfactory owing to hydration effects. The most satisfactory method for determining free lime is a thermal method in which the cement is heated at a temperature of 900°C for 10 minutes, converting the calcium hydroxide into calcium oxide, which is then determined by the rise in temperature produced when it is mixed with water. This gives reliable results for set and unset cements, and is particularly valuable in investigating the fire-resisting properties of cement or concrete. F.P.H.

New system of cooling cement clinker. FELLNER AND ZEIGLER. *Zement*, **29**, 519–20; *Rock Products*, **30** [2], 98 (1927).—The present-day operation of rotary cement kilns proceeds with a more or less excess of air. Little value is placed on making the intake end of the kiln air-tight and the discharge end serves merely as a place where the clinker is to be cooled. For this purpose, the hot clinker is allowed to drop into a separate rotary cooler where it is cooled and the hot air drawn off by air exhaust fan and passed back into the kiln or used for other purposes. The new process for cooling cement clinker uses a "Stehmann" cooler. By this method only the theoretical amount of air is allowed to enter the kiln and thus a minimum of fuel is used. The entire kiln is made air-tight and calcining and discharge of hot clinker carried out in such a way that no outside air is admitted. This is accomplished by erecting a sealed enclosure about the stack and the head of the kiln to eliminate the possibility of outside air entering. The clinker cooling chamber is of masonry construction and equipped with one or more cast iron shaking grates. These grates are placed directly over each other so that the

hot clinker coming from the kiln first falls on the top grate where it is spread uniformly over the grate surface by the shaking action. Cold air is admitted from the bottom of the chamber and passes up and through the grates absorbing heat as it does so. This air is under pressure of from 500–600mm W. S. and the amount admitted limited, usually about three-fourths of that required to mix with fuel for calcining the slurry. The arrangements are such that conical heaps of clinker on the grates are avoided and thus a constant pressure is always present in the cooling chamber; this permits easy regulating of the air supply. The heated air passes directly up and through the top grate and then passes through a right-angle-bend pipe to the fire box where it is mixed with the fuel. The right angle turn the hot air makes is of particular importance for in this way the air gets a thorough washing and cleaning or separation from any clinker dust particles that might have been carried with it into the fire box. The strongly preheated air coming in contact with the fuel in the fire box accelerates combustion to such a great degree that unless the carrying air (cold air from the ventilator) has a great velocity, the hot flame will spread close to the kiln discharge end, a point where it is least efficient. Only one-fourth of the air used comes from the cold air ventilator and even this is regulated by the amount of preheated air received from the cooling chamber. The cooling clinker is now allowed to pass through bottom grate into a hopper equipped with automatic opening and closing gates. These gates are opened and the clinker falls into another hopper similar in design. Both these hoppers are connected with exhaust fans to draw off the air which contains any heat that may have been absorbed from the cooling clinker. The arrangement of the automatic gates is such that when the gate on the upper hopper is opened the bottom hopper gate is closed and the whole becomes an air-tight chamber. In the same way, when the gate on the bottom hopper is opened, the upper hopper gate closes. In this way a continuous automatic cooling process for the clinker has been developed wherein each hopper is a self-contained unit and air-tight. The completely cooled clinker now passes out of the bottom hopper onto a belt conveyer, or other type of conveyer and is carried to storage or the finish-grinding mills. As stated before, the stack in this process serves merely to carry off the waste gases. Any tendency for air to be sucked into the kiln through the stack should be watched and there should always be maintained a slightly greater pressure at the kiln head than at the stack. For this purpose, a Venturi meter with a registering device is placed in the air line. Through this, it is possible to control and regulate conditions in the cooling chamber. The first application of this cooler system on a rotary cement kiln is said to have shown a saving of 20% in fuel and this is expected will be even greater when the principles are better developed. F.P.H.

Rapid determination of silica and lime in raw cement mixture. ANON. *Zeit. angew. Chem.*, **39**, 278; *Rock Products*, **30** [3], 83 (1927).—Silica is determined in the raw mixture used for making blast furnace cement by digesting a small sample with concentrated hydrochloric acid, evaporating to dryness and treating the residue with dilute acid, then filtering and weighing. The filtrate is made alkaline with ammonia and then acid with acetic acid. Iron and aluminum are precipitated as phosphates and without filtering calcium is precipitated as oxalate. The combined precipitates are purified by redissolving and precipitating, and are finally dissolved in sulphuric acid and lime determined by titrating the oxalic with potassium permanganate. F.P.H.

Changes in physical state of cement during setting. ANON. *Giorn. Chim. Ind. Appl.*, **8**, 469–72 (1926); *Rock Products*, **30** [3], 83 (1927).—The changes in the specific gravity and in the quantity of water uniting with cement during setting show that the quality of a cement depends on its ability to combine with a large proportion of water in minimum time, this determining the compactness and the strength of the product. The rapidity of hardening increases with the fineness of the cement and the quality of

the latter depends largely on the system of firing employed. Since the difference between the specific gravity of the aggregate and that obtained after it has hardened in water for a given time determines its strength, it is possible to obtain a rapid measure of the intrinsic value by 2 measurements of the specific gravity at a short interval. F.P.H.

Studies of properties of plaster of Paris. ANON. *Bull. Soc. d'Encour.*, **125**, 789–803 (1926); *Rock Products*, **30** [6], 82(1927).—Chassevent studied the setting properties of plaster of Paris by measurements of the electrical conductivity of the solution forming in the immediate vicinity of the plaster and also by the heat changes involved. F.P.H.

Changes in viscosity and water content of cement slurry. CURT PRUSSING. *Zement*, Nov. 4 and 11, 1926 reprints a report at the 1926 convention of German Portland Cement Manufactures; abstracted in *Rock Products*, **30** [6], 82(1927).—The tests described in this report were inspired by a description of American methods of manufacture published by Dr. Müller, wherein a statement was made that at the Ford Motor Co's. cement mill at Detroit, Mich., dextrine was regularly added to the slurry. This appeared to be of special interest to P. as he had had experience with shale which decreased the viscosity of the slurry. The purpose of the tests was: (1) to find a practical method whereby the relative viscosity of the slurry could be expressed numerically; (2) to find means of regulating the viscosity of the slurry in the simplest way possible; (3) to find which constituents of the shale react with the admixtures. To solve the latter problem hundreds of tests were made on synthetic mixtures made by combining colloidal silica, alumina, and iron oxide in different proportions. The effect on the viscosity of the mass of alkaline admixtures such as soda, sodium hydroxide, calcium hydroxide, and iron hydroxide was studied. It was found that the extent of oxidation of the iron constituents of the shale was of great influence on the viscosity of the mass produced by the addition of alkalis. F.P.H.

A scientifically controlled lime kiln. W. H. BARTON. *Rock Products*, **30** [7], 34–36(1927).—A description of the kiln of the Blue Diamond Co. The kiln is operated from one control board on which are located instruments that indicate the exact conditions existing within the kiln. F.P.H.

Steam in limestone decomposition. VICTOR J. AZBE. *Rock Products*, **30** [7], 63–65 (1927).—A. states that contrary to general belief steam does not help calcination and presents data to substantiate his claims. F.P.H.

Effect of the calcination process on the properties of Portland cement. E. ULLRICH. *Zement*, 72–74, 91–94(1927); *Rock Products*, **30** [7], 80(1927).—A thorough review of all investigations of this subject are given. The different compounds in the 3-component system of lime–silica–alumina are discussed. The history of the discovery of alite, belite, celite, and felite crystals is given. Upon discovering that alite was most important to the hydraulic properties of cement, considerable research has been repeatedly made on this compound. Meyer, Tschernobaeff, Dittler, and Jesser made the first investigations of this mineral. In more recent times extensive investigations were made by Nacken and Dyckerhoff. Their fundamental procedure was that of heating mixes to 1500°C and determining the binary and ternary compounds and their formation. The thermochemical effect was studied and confirmed by thermoanalyses of the formation of clinker from samples of the raw mix obtained from different plants. Whenever possible, microscopic studies were made to identify the compounds thus found in the clinker. The following compounds were found in the Portland cement clinker: $2CaO \cdot SiO_2$; $3CaO \cdot SiO_2$; $CaO \cdot Al_2O_3$ $3CaO \cdot Al_2O_3$; $5CaO \cdot 3Al_2O_3$, and $8CaO \cdot 2SiO_2 \cdot Al_2O_3$. The existence of $3CaO \cdot SiO_2$ and $8CaO \cdot 2SiO_2Al_2O_3$ was definitely proved. The properties of all compounds were carefully studied, particularly the 3 forms of $2CaO \cdot SiO_2$, which received special attention. Formation of these compounds begins at 1050°C and in-

creases rapidly with pronounced exothermic reaction between 1100 and 1200°C. The heat curves of different synthetic and raw mixes were also plotted, and the gradual formation of the different crystal compounds determined exactly. Microscopic investigation of synthetic clinker (Al_2O_3, CaO, and SiO_2) sintered for 20 minutes at 1500°C show it to have the following composition: about 60% $2CaO \cdot SiO_2$ (chiefly in β form); $3CaO \cdot Al_2O_3$; $5CaO \cdot 3Al_2O_3$, and a little free lime. Nacken and Dyckerhoff are of the opinion that the alite (β-$2CaO \cdot SiO_2$) is in solid solution with about 10% of CaO, although its optical properties show but little variation. This theory found strong contradiction in Kuhl's researches, who maintained that assuming $2CaO \cdot SiO_2$ to be in solid solution with 10% lime in the presence of aluminates of highest lime content, there would still remain 10% CaO, which would presumably exist free in all Portland cement clinkers. This is true, however, of only unsound clinkers and is not always present even in these. Kuhl also claimed that a modification of the dicalcium silicate was more probable. He also doubted the existence of free aluminates in the clinkers, as they crystallized readily, yet no such crystals were observed in the clinker. Kuhl's tests also indicated higher temperatures, 1340–1350°C, at which normal time of set, normal color, strength, and soundness could be expected of the clinker. He also differed from the other investigators on the determination of alite, claiming that the optical tests of the compound were not able to definitely isolate it. Biehl made a study of the effect of calcination temperature, period of calcination, and speed of cooling on the hardening properties and crystalline formation of clinkers. He concluded that longer calcination and higher temperatures improve the quality of Portland cement similar to fusion. F.P.H.

Concrete improved by the use of diatomite. V. L. Eardley-Wilmot. *Contract Rec. Eng. Rev.*, **41,** 331(1927).—As an admixture in concrete, this material increases workability, strength, and waterproofness. Tests are now being conducted by the Department of Public Works of Canada, in coöperation with the Mines Branch to determine the suitability of Canadian diatomite for use in concrete mixes. O.P.R.O.

Cement in 1926. A. T. Green. *Ann. Rept. Soc. Chem. Ind.*, **11,** 246–51 (1926).—The subject is reviewed under the headings: Constitution of CaO–SiO_2–R_2O_3 cements, properties of cements and concretes, and magnesian cements. Under the first heading, Jänecke's view that cement clinker contains $2CaO \cdot SiO_2$ (belite), $3CaO \cdot SiO_2$, $3CaO \cdot Al_2O_3$, $5CaO \cdot 3Al_2O_3$, $8CaO \cdot Al_2O_3 \cdot 2SiO_2$ (Le Chatelier's alite), $2CaO \cdot FeO_3$ (celite), and free CaO is given prominence. Baykoff suggests that setting takes place in 3 stages: (1) dissolution, during which the liquid is progressively saturated with different soluble substances; (2) colloidization, the stage corresponding with initial set; (3) crystallization. Bennett and Bakewell assert that the strongest cement used in building practice is the cement prepared by mixing MgO with $MgCl_2$, but that since such a product rapidly corrodes iron and steel work, $FeCl_2$ may be substituted for $MgCl_2$. H.H.S.

Gypsum products in Canada in 1925. Dominion Bureau of Statistics. *Chem. and Ind.*, **46,** 243(1927).—Gypsum products classified as "miscellaneous nonmetallic mineral products" amounted in value to $1,001,509. Eight plants were in operation, capital totalled $640,486, employees numbered 213, and raw material cost $348,046. Wall-coating gypsum board and gypsum blocks were made in 3 plants in this industry, and the output was valued at $864,483; in addition hard wall plaster and some wallboard was made in plants which quarry gypsum and are therefore included in the mineral production group. Plaster castings and ornamental plaster works made up the bulk of the remainder of output. H.H.S.

BOOK

Concrete Yearbook. O. Faber and H. L. Childe. 4th edn. London: Concrete Publications, Ltd., 1927. Price 2 *s.* 6 *d.* H.H.S.

PATENTS

Improving properties of hydraulic cement. Ger. Pat. 73,577; *Rock Products*, **30** [1], 79 (1927).—The raw materials are ground finer than usual and calcined at lower temperatures than customary. The calcining period may also be lessened or both time and temperature of calcination be diminished simultaneously if desired. Fine grinding may be carried on either before or after calcination. Investigations have proven that finer grinding of raw cement materials permits the use of lower calcining temperatures and results in materially lessening the time of calcination and yields a better cement. F.P.H.

Hydraulic cements from oil shale and limestone. Ger. Pat. 427,801 and 429,651; *Rock Products*, **30** [1], 79 (1927).—Oil shale is mixed with a comparatively large proportion of limestone, lime marl and the like, 30 to 50% being employed for this purpose. No fuel is added and the mixture is heated in suitable apparatus. The residue consists of a hydraulic cement; the various oils and other volatile distillation products are collected and treated further. The fused residue obtained at the outset is also moistened with the ammoniacal liquors that are recovered in the course of the distillation process and this serves to improve the quality of the cement and at the same time allows ammonia to be involved and recovered. . F.P.H.

Slag cements resistant to salt water. Ger. Pat. 421,776; *Rock Products*, **30** [1], 79 (1927).—Blast furnace slag is mixed with clinker containing a large percentage of alumina and the mixture ground fine. Proportions of the ingredients are maintained at about the ratio used in making blast furnace or iron Portland cements. Cements made in this way are said to be more resistant to the action of salt water than pure aluminous cements and, in addition, are cheaper to produce than the latter. F.P.H.

Processing cement. Ger. Pat. 434,187; *Rock Products*, **30** [1], 79 (1927).—Molten cement is passed directly into a special chamber where it is mixed with other materials and then subjected to a reducing action. A special rotary kiln is used to melt the cement, the hottest part being located near the outlet. The flame and flow of material may be in the same direction or countercurrent. F.P.H.

Ciment fondu composition. French Pat. 607,577; *Rock Products*, **30** [1], 79 (1927).—A mixture of bauxite and other materials, such as alumina, iron oxide, silica, and titanium dioxide, to which the equivalent proportions of lime have been added, is calcined and fused in an oxidizing atmosphere in a rotary kiln. The mass is allowed to cool and is then ground fine. Resulting cements are said to be quick setting and hardening and have great bonding strength. F.P.H.

Aluminous cements. French Pat. 608,162; *Rock Products*, **30** [1], 79 (1927).—A mixture of about 75% bauxite and 25% limestone or lime hydrate is calcined in a usual type of rotary kiln at a temperature between 900 and 1100°C for a period of from 8 to 12 hours. The mass is then cooled and ground. Cements made in this way are said to have a hydraulic modulus of more than 2. F.P.H.

Lime manufacture. Brit. Pat. 256,687; *Rock Products*, **30** [1], 79 (1927).—Limestone is ground to 40-mesh and heated to about 850°C in the presence of an oxidizing agent such as oxygen or steam. Rotary electric kilns of the muffle type are desirable calciners. F.P.H.

Aluminous cement. Brit. Pat. 259,203; *Rock Products*, **30** [1], 80 (1927).—An aluminous cement clinker which on slow cooling spontaneously disintegrates, contains at least 25% of alumina and has a silica content of between 0.4 and 0.5 of the alumina content, while the lime content is from 3 to 3¼ times the silica content. White bauxite and pure limestone may be used as raw materials for production of a white cement. F.P.H.

Manufacture of fused cement. French Pat. 604, 916; *Rock Products*, **30** [1], 80 (1927).—A mixture of raw cement materials is sintered in a refractory lined rotary kiln and the sintered mass fused on leaving the furnace. For this purpose the metal wall of the furnace or kiln in the region of the outlet is enlarged in the form of a disk and connected with one pole of a source of current of low tension and high intensity. The disk is set obliquely and can be adjusted by means of a hinge and spring with respect to a metal or graphite plate which is connected with the other pole of the source of current. The sintered mass falls between the disk and the plate, closing the circuit, and is fused by the high heat created from the resulting short circuit. F.P.H.

Calcination of limestone in electric furnace. J. K. KIDDLE. Brit. Pat. 256,687; *Rock Products*, **30** [7], 80 (1927).—Calcium carbonate is ground to pass a 40- or finer per sq. in. mesh sieve, and then subjecting the granular material to heat, such as passing it through an electric furnace capable of attaining a temperature of between 700 and 900°C for a period of time to produce pure CaO, such furnace being controlled to attain the desired temperature, and neither more or less, so as to prevent overfiring or underfiring. It is preferred also to agitate the contents of the furnace in any suitable way during the firing process. F.P.H.

Enamel

Some effects of varying soda and boric oxides in ground coat enamels. R. R. FUSSELBAUGH. *Jour. Amer. Ceram. Soc.*, **10** [4], 270–74 (1927).—Variations were made from 5 to 25% in soda oxide and boric oxide content of a given ground coat enamel, and results observed on trial pieces. It was found that an increase of soda oxide at the expense of boric oxide decreased the tendency of the enamels to blister and fishscale, and increased the tendency toward the formation of copperheads. Conversely, the increase of boric oxide at the expense of soda oxide increased the tendency of the enamels to blister and fishscale, but decreased the tendency to copperhead.

Agreement of ground coat and enamel. A. MALINOVSZKY. *Jour. Amer. Ceram. Soc.*, **10** [4], 275–77 (1927).—Troubles in working with enamels may be caused by poor workmanship in some department or by changes in composition of the enamel due to differences in chemical composition of raw materials used. The application of Staley's refractory ratio in determining the agreement of ground coat and enamel cover coat is illustrated.

Use of muffle furnace in the testing of vitreous enamels. C. F. LAI. *Jour. Amer. Ceram. Soc.*, **10** [3], 150–62 (1927); abstracted in *Fuels and Fur.*, **5** [3], 325–26 (1927); for abstract see *Ceram. Abs.*, **6** [5], 168 (1927).

Use care in selecting ceramic fuels. ANON. *Ceram. Ind.*, **8** [4], 430 (1927).—It is pointed out that the trend in all ceramic plants is toward a fuel that produces a clean furnace condition, is capable of being accurately controlled with regard to both temperature and atmospheric conditions, is simple to handle or apply, and is reasonable in cost per 1,000,000 B. t. u. and in cost of furnace operation and maintenance. There is a proper balance between these factors as to the best fuel for any definite ceramic product. F.P.H.

Application of fuels in enameling furnaces. F. M. BURT. *Ceram. Ind.*, **8** [4], 430–32 (1927).—A summary of the kind of enameled ware, the number of plants and furnaces, and the fuel used in the different plants is given in a table. It is claimed that there are 1171 enameling furnaces in 178 plants representing an investment of over 4 million dollars. It is claimed that 60% of these are operating. F.P.H.

Coal is low priced fuel for enamelers. F. M. BURT. *Ceram. Ind.*, **8** [4], 434–35 (1927).—The chief advantage in the use of coal as a fuel in enameling is that of price. It is claimed that the quality of ware produced in a properly built and fired coal furnace,

with a tight muffle, whether sheet steel, wet or dry process cast iron, is as good as with any other fuel. F.P.H.

Gas as a fuel for enamelers. F. M. BURT. *Ceram. Ind.*, **8** [4], 439–40(1927).—The advantages of gas as a fuel: comparatively cheap in some and very cheap in other localities, easiest to handle, best of combustion possible, very clean, best adapted to exact control, and lends itself to the evenest of heat distribution. F.P.H.

Enamelers can save with electricity. CARL MEHLING. *Ceram. Ind.*, **8** [4], 447–49 (1927).—Points out advantages of electric furnaces. F.P.H.

Ferrous metallurgy and corrosion. ANON. *Chem. and Ind.*, **46**, 209–12(1927).—To all industries that use metal in any form, the recent advances in metallurgical knowledge constitute an important advantage, and chemical engineers benefit by them. The new steels are divided into 3 groups: those containing high Ni and low Cr, those containing low Ni and high Cr, and those comparatively high in both Ni and Cr. The first group is resistant to acids other than HNO_3 and to salts, especially when containing a few % of Mo. The second group is immune to HNO_3 and to contaminated atmospheres. The third group gives general resistance at high temperatures. H.H.S.

Iron and steel in 1926. C. O. BANNISTER. *Ann. Rept. Soc. Chem. Ind.*, **11**, 252–68 (1926).—A paper by Hansen and Lindsey (*Jour. Amer. Ceram. Soc.*, **9** [8], 481–92 (1926).) on pickling is reviewed. Pfeil used electrolytic pickling and found that occluded H has a considerable weakening effect on tensile strength. Fuller's analysis of electrolytic iron, after annealing to remove H, is: Fe 99.965 %, Cu 0.015 %, and approximately 0.005 % each of C, Si, S, and P. This metal can be annealed at a high temperature and quenched at once, in cold water without appreciably changing its properties. Kistiakovski considers that iron may exist in 5 distinct conditions ranging from "superactive" to "passive." In the former state there is an unbroken coating of hydride, in the latter of oxide, and in neither is it possible for the iron to rust. When either coating is ruptured local currents are produced and rusting sets in. The accelerating effect of CO_2 on rusting is attributed to its depolarizing action on the local currents. B. reviews progress under the headings: production foundry practice, manufacture of steel, cementation and case-hardening, properties of iron and steel, and corrosion. H.H.S.

Glass

A method for measuring the softening temperature of glasses. J. T. LITTLETON, JR. *Jour. Amer. Ceram. Soc.*, **10** [4], 259–63(1927).—For the purpose of measurement the softening point of glasses is defined as that temperature at which a uniform thread of glass .65 mm to 1 mm in diameter suspended in a vertical position in an electric furnace of specified characteristic will elongate at the rate of 1 mm per minute. The measurements on a given glass are reproducible to within 1 to 2°C. This method has been found useful as control of glass composition in melting units as well as a point of reference to distinguish between different glasses. Data are given showing the variation in softening point of a tank glass and a pot glass over an interval of time.

Glass tank of tunnel kiln possesses many advantages. WARREN S. WILLIAMS. *Fuels and Fur.*, **5** [3], 319–20(1927); published *Jour. Amer. Ceram. Soc.*, **10** [3], 205–09 (1927); abstracted in *Ceram. Abs.*, **6** [5], 169(1927). A.E.R.W.

Investigation of the glassy state by the method of forced crystallization. J. F. PONOMAREFF. *Fuels and Fur.*, **5** [4], 460(1927).—Abstract of paper presented before the Society of Glass Technology. A.E.R.W.

Batch melting experiments with batch materials containing chemically combined water. E. M. FIRTH, F. W. HODKIN, M. PARKIN, AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **10** [40], 364–73(1926).—Batches with calcined alumina, giving a glass with about 4% aluminum oxide, melt more rapidly than those with a corresponding

amount of hydrated alumina and do not give so persistent a frothy boil; they were also 'sweeter', less quick setting, and not so brittle. The complete substitution of crystallized sodium carbonate for soda ash gave scummy, stony, and wavy glasses, more viscous than those of the same composition made from soda ash. Little difference was observable between the action of boric acid, fused borax, calcined borax, and crystalline borax in batches giving glasses with only 1 to 2 % boric oxide, but in batches giving glass of about 20 % boric oxide content, the most rapid melting rate was shown by the fused borax batch, while the boric acid batch melted more rapidly than those containing calcined or crystalline borax. Refining was most rapid with the crystalline borax batch, while those from fused borax gave persistent fine bubbles. Glasses of the same composition made from these different materials showed little differences in working properties, those from fused borax or boric acid being slightly the best. The crystallized borax batches gave glass of the best color; this is in striking contrast to the action of soda lime silica or other batches without boric acid containing large amounts of water. D.J.McS.

Some glasshouse tests to determine differences in the general characteristics and in the working properties of molten glass. W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **10** [40], 374–84 (1926).—A series of glass melts in pots strikingly confirms the practical glass worker's belief in the existence of the property he terms 'nature', *i.e.*, variations in the working character and mechanical properties of glasses independent of variations in the glass forming constituents, but resulting from variations in batch or heat treatment, or in the amounts of moisture, arsenic, and other minor constituents. A skilled glassworker on working glass from such different batches was able to detect differences in the working or other properties of the glasses of such a nature as to be able to deduce the differences between the glasses from these various batches. D.J.McS.

Cumberland glasshouses. F. BUCKLEY. *Jour. Soc. Glass Tech.*, **10** [40], 384–86 (1926).—A short account of the glasshouses in Cumberland, England, during the 18th century. D.J.McS.

A ten years' retrospect. W. BUTTERWORTH. *Jour. Soc. Glass Tech.*, **10** [40], 386–98 (1926).—Presidental address reviewing the growth of the Society of Glass Technology since its foundation. D.J.McS.

The year's progress in the study of glass at Sheffield. W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **10** [40], 398–404 (1926). D.J.McS.

Some corrosion and erosion phenomena and their bearing on the macrostructure of refractories. J. F. HYSLOP, R. GUMM, AND H. BIGGS. *Jour. Soc. Glass Tech.*, **10** [40], 405–12 (1926).—From action of organic solvents on mixtures of clay grog and wax, simulating clay refractories, authors conclude that in clay refractories used against glass, the grog should be fine when the solution of the refractory in the glass is lighter than the glass, and should be coarse when this solution is heavier than the glass. Where erosion is the main factor of refractory break-up, the grog should be fine. D.J.McS.

The viscous properties of glass. V. H. STOTT. *Jour. Soc. Glass Tech.*, **10** [40], 424–34 (1926).—Viscosity measurements on a glass show that when the glass is maintained for some time within a critical temperature range below 1200°C, marked anomalies in the viscosity result. S. discusses possible causes of this phenomenon and viscosity in general. D.J.McS.

Tell of industrial glass products of Corning factory. ANON. *Amer. Glass Rev.*, **46** [24], 14 (1927).—A note regarding industrial glass produced by the Corning Glass Works. E.J.V.

Amco "L" continuous glass melting tank. ANON. *Amer. Glass Rev.*, **46** [24], 17–18 (1927); *Nat. Glass Budget*, **42** [46], 3 (1927); *Glass Ind.*, **8** [4], 96 (1927).—A description of an "L" tank glass furnace developed by Amsler-Morton Co., of Pittsburgh. It is in successful operation producing flint glass of high quality from a relatively small hearth of shallow depth. Details of design and various features are discussed. E.J.V.

Pittsburgh and the glass industry. WILLIAM L. MUNRO. *Amer. Glass Rev.*, **46** [25], 15(1927); **46** [26], 15(1927); *Nat. Glass Budget*, **42** [47], 3(1927).—An address before the Pittsburgh Chamber of Commerce on March 15, 1927, taking up the development and progress of glass manufacture in the Pittsburgh district, reasons for centering of the glass industry in that district, and outlining methods of manufacture. E.J.V.

San Francisco a factor in glass industry. ANON. *Amer. Glass Rev.*, **46** [26], 19 (1927).—A description of the modernly equipped and operated plants of the Illinois-Pacific Glass Co., and the Pacific Coast Glass Co., both thriving institutions located in San Francisco. E.J.V.

Glass perfected in Germany said to withstand heat and acid. DOUGLAS MILLER. *Amer. Glass Rev.*, **46** [27], 14(1927); *Nat. Glass Budget*, **42** [49], 26(1927).—A glass made into tube water gages which sustain cold water pressures of 20, 45, 65, 80, and 100 atmospheres and bars of which withstand a sudden change from 160° to 0°C without suffering any damage is being worked successfully in Germany. E.J.V.

Tygart Valley Glass Company starts its new factory at Washington, Pa. J. M. HAMMER. *Amer. Glass Rev.*, **46** [27], 15–17(1927); *Nat. Glass Budget*, **42** [49], 3(1927). —A description of the new plant and equipment thereof at Washington, Pa., built to replace the factory which burned down in Grafton, Pa., a year ago. It is modern in every respect and has every facility for quality output on a quantity basis. E.J.V.

Technical control of automatic production in glass factories. ANON. *Amer. Glass Rev.*, **46** [29], 15(1927); reprinted from *Pottery Gaz.*, **52** [597], 475–80(1927); see also *Ceram. Abs.*, **6** [5], 171(1927). E.J.V.

Removing glass with paving breakers. ANON. *Amer. Glass Rev.*, **46** [29], 17(1927). —In tearing out an old glass tank to build a new one it was found necessary to remove approximately 398 cubic yards of glass from the bottom of the old tank. An 80-pound paving breaker (pneumatic chisel) was used. An analysis of cost by this method and by the hand method shows a total saving of over $2,000 by the paving breaker method. E.J.V.

Making of incandescent lamps described. HENRY SCHROEDER. *Amer. Glass Rev.*, **46** [31], 16(1927); reprinted from *New York Times*.—The processes used in the manufacture of incandescent lamps, as well as some of the many improvements made within recent years in construction detail, are described in a nontechnical way. E.J.V.

Brilliancy and composition of glassware. OSCAR KNAPP. *Glass Ind.*, **8** [4], 73–74 (1927).—A high degree of brilliancy is desired in the case of hollow ware and cut glassware. The brilliancy of the glass is dependent on its index of refraction, the higher the index the greater the brilliancy. Zschimmer found the value of the index of refraction grew with the increase of the molecular weight of the glass-forming oxide used. A study of the relationship between refractive power and chemical composition made by K. showed a direct proportionality between these 2 factors. The power of refraction of glass is an additive property of the refractive powers of the glass forming oxides and may be calculated by use of the following equation: $n_D = a_1 n_{D1} + a_2 n_{D2} + a_3 n_{D3} + \cdots$ etc., where a_1, a_2, a_3, etc. represent percentages by weight and n_{D1}, n_{D2}, n_{D3}, etc., represent the refractive indices of the g'ass-forming oxides. These values for the components of hollow ware are as follows:

SiO_2	0.01467	CaO	0.01776
Na_2O	0.01575	MgO	0.01655
K_2O	0.01551	Al_2O_3	0.01581

A comparison of values obtained by experiment and calculated values showed small differences, showing that it is possible to calculate the power of refraction of glasses in advance by use of this rule. E.J.V.

The deformation of glassware due to unequal cooling during manufacture. ROY. E. SWAIN. *Glass Ind.*, **8** [4], 74–76(1927).—The shrinkage of glass in cooling, states of thrust and tension produced in the different layers of the glass due to unequal cooling, and deformations due thereto are discussed. The warping of pressed ware and methods used to inhibit it are explained. The defects known as "magic blisters" observed in font mold pressed ware are also due to unequal cooling and shrinkage of the glass. E.J.V.

On the dispersion of light by glasses and its measurement. H. SCHULZ. *Glastechn. Ber.*, **4** [3], 81–92(1926).—A mathematical and physical discussion of light dispersion by glasses is presented. The dispersion capacity of opaque glasses can be characterized by means of the following data: (1) direct transmission; (2) strength of the diffused light; (3) non-uniformity of division of light; and (4) absorption. Methods and apparatus for the determination and measurement of light dispersion are described. E.J.V.

Investigation of glass in tension. F. SPÄTE. *Glastechn. Ber.*, **4** [4], 121–29(1926). —A technical, illustrated discussion of the determination of tension in glasses by use of polarized light. The effects observed with and without crossed nicols, etc., are illustrated and explained. E.J.V.

The valence of arsenic and antimony in glass. H. HEINRICHS AND F. SALAQUARDA. *Glastechn. Ber.*, **4** [4], 130–37(1926).—Analyses of glasses were made to determine the valence of arsenic and antimony in them. These were made by distilling a mixture of glass, potassium iodide, and hydrochloric acid in an atmosphere of CO_2, reducing the pentavalent to the trivalent form and oxidizing the iodide to metallic iodine which was then titrated with $Na_2S_2O_3$. Results obtained show that from 75–85% of the arsenic is present in the pentavalent form while only 0 to 6% of the antimony introduced is in the pentavalent form. E.J.V.

New ideas on the constitution of glass. H. SALMANG. *Glastechn. Ber.*, **4** [5], 172–79(1926).—Experiments and investigations to ascertain the synthesis of glasses are discussed. Electrolysis of glasses at high temperatures shows that the alkali silicates formed can be dissociated. These form about 15 to 35% of the glass. Under the products of devitrification are listed the various findings of Morey and Bowen on the ternary system CaO–Na_2O–SiO_2. Other items discussed include: physical properties and heat treatment; molecular complexity; the chemical combinations in glass; and the fine structure of glass. E.J.V.

Glass—the incomparable; glass—the mysterious. JAMES MORRISON. *Nat. Glass Budget*, **42** [48], 3(1927).—A discussion showing the vital part glass plays in the onward march of civilization. Its many uses, applications, and services which would not be possible without glass are enumerated and discussed. E.J.V.

Report of Society of Glass Technology meeting. ANON. *Nat. Glass Budget*, **42** [50], 20(1927).—Abstracts of the following papers read at the March 16th meeting are given: "Some Further Developments in Recuperative Glass Furnaces," by Th. Teisen; "The Properties of Some Soda–Lead–Oxide Glasses," by Violet Dimbleby, W. E. S. Turner, and F. Winks. E.J.V.

Future trend in plate glass manufacture. GEORGE E. HOWARD. *Nat. Glass Budget*, **42** [51], 3(1927).—The market structure in the plate glass industry has been dislocated by the sudden demand for glass for closed automobiles. The former structure of the market is described and analyzed. Where small size (ten square feet and under) plates formerly made up 35% of the market they now constitute nearer 80%. This demand led to the development of the continuous tank process. Future production structure, and the future of the pot method and tank method are discussed. E.J.V.

New Frink developments surpass expectations. ANON. *Nat. Glass Budget*, **42** [51], 3(1927).—A description of the shops and equipment of the Frink Pyrometer Co.,

and Frink Laboratories at Lancaster, Ohio. The completeness and up-to-date nature of all equipment used is stressed. A new refractory known as "Frinkite" has been developed. Pieces made of it were taken from the drying oven, thrown into a furnace having a temperature above 2400°F, allowed to heat through thoroughly, and then dipped into water with no apparent rupture or disintegration resulting. A recuperator made of "Frinkite" operating so that one end is at 2600°F while the other approximates 500°F is described. Further developments being planned are mentioned. E.J.V.

Develop colored glasses. BUREAU OF STANDARDS. *Nat. Glass Budget*, **42** [51], 25(1927); reprinted from *United States Daily*.—The Bureau of Standards is engaged in the development of colored glasses, used in science and industry. Standard colored glasses are used for such purposes as rating mineral or vegetable oils, and it is the purpose of the Bureau of Standards to grade the color discrepancies now found in the Lovibond scale, the complete set for which normally consists of 465 glasses. E.J.V.

Recent progress in the glass industry. W. E. S. TURNER. *Chem. and Ind.*, **46**, 234–36(1927).—There are 383 glass factories in Germany, 310 in the U. S., and 115 in Great Britain, and the numbers of employees are in the same order. Two generations ago, England was an exporter of glass; today she is flooded by the Continental factories. During the same period, German exports have continually risen, but in optical glass they have not recovered their pre-war position. Amalgamations of firms have taken place in the German optical glass trade, and today there is practically only one firm. In Canada there are 8 glass factories; in Australia a big combine of bottle manufacturers has taken place; in Japan, also, bottle making has made considerable progress, as well as some window and sheet glass; and the glass industry has been established in S. America. Refractories have been vastly improved; formerly they did not last for more than 5 or 6 weeks, now they are good for 10–11 months, and some have been known to stand up for 3 or 4 years. A U. S. development is the electric fusion of refractory blocks instead of cementing them together with some heat-resisting cement. The manufacture of electric lamp bulbs was then dealt with, and various types of bottle-making machines discussed, and it was claimed that in chemical glass British ware is very much superior to German. In the discussion, Redfern said that the Lumb Co. was making for Mitsubishi Shoji Kaisha Ltd. a bottle-making machine capable of producing 40 million bottles a year. The question of workman's skill was touched on by Collet, Cox, and others; it was said that Belgian glass workers have an unsurpassed intuition for the work, and that those of Czechoslovakia and Germany preserved an inherited tradition of workmanship. H.H.S.

Glass in 1926. A. COUSEN. *Ann. Rept. Soc. Chem. Ind.*, **11**, 199–216(1926).—Samsoen's researches have shown that the thermal expansion of a glass is not in additive relation to the constituent oxides; the coefficient of expansion increases with increase of temperature, and there is a transition temperature above which the rate is greatly increased. Samsoen also found that many amorphous organic compounds with widely differing chemical properties exhibit a similar increase of coefficient of expansion when the temperature was such that the viscosity had reached a value of 10^{14} poises. C. is of opinion that although the past year has witnessed no falling off in the total amount of work published on glass technology, advance has been somewhat unequal in the various branches of the subject. The fundamental problem of the constitution of glass, in which notable progress had been made during the previous year, has not been developed as one might have expected. Progress is then considered under the headings: melting, constitution, devitrification, mechanical properties, expansion, viscosity, endurance, annealing, refractive index and dispersion, scattering of light, color, decolorized glass, absorption of light durability, glass types, and furnaces. H.H.S.

[**Optical Glass.**] **Progress in optics.** L. C. MARTIN. Cantor Lectures, Roy. Soc. Arts. *Engineering*, **123**, 141–42(1927).—Before the war, England imported 60%

of her optical glass from Germany and 30% from France. Today British factories can supply any requirements, and new types of glass are obtainable which are not made elsewhere. The biggest firms are Chance Bros., Barr & Stroud, and Parsons. Of all problems in glass manufacture, none is more important than annealing. The work of Twyman, and, in the U. S., of Adams and Williamson, determined the range of temperature over which cooling should take place very slowly, and thus enabled the cooling and annealing process to be reduced in time from 12–3½ days. Considerable advances have been made in the last few years in increasing the transparency of glass. The remainder of the 3 lectures is devoted to the manufacture, use, and testing of optical instruments.

H.H.S.

Studies of the conduction process in glass. I. Replacement of the sodium by alkali metals and ammonium. C. B. HURD, E. W. ENGEL, AND A. A. VERNON. *Jour. Amer. Chem. Soc.*, **49**, 447–50(1927).—Ordinary W-filament electric light bulbs made of glass containing SiO_2 72.44, Na_2O 17.06, CaO 5.02, MgO 3.77, Al_2O_3 0.97, Fe_2O_3 0.72%, As_2O_3 trace, were suspended in electrolytic baths. A *C*-rod in the electrolytic bath was made the anode of a d.c. circuit and the lamp filament the cathods. When the filament was lighted, thermionic emission across the evacuated space in the lamp completed the circuit. The positive ions passed from the anode through the electrolyte and through the glass to the interior wall of the bulb. By immersing the bulb in electrolytes of NaCl, $Na_2Cr_2O_7$ solutions, fused $NaNO_3$–$NaNO_2$ mixtures, KCl solution, fused KCNS, fused $LiNO_3$, saturated NH_4Cl solution, or fused NH_4OAc it was possible to replace more or less of the Na of the glass by the anion of the electrolyte. The effect of the replacement on the character of the glass varied according to the nature of the replacing anion. The ease of replacement seemed to depend upon the relationship between the size of the Na-ion and the ion replacing it. (*C. A.*)

The weathering of glasses. I. K. TABATA, K. YEGAMI, AND S. MORIYASU. *Researches Electro-Tech. Lab., Japan*, No. 179, 11 pp.(1926); (in English).—Experiments on the weathering of flint glasses are described. The weathering action is caused by the alkali silicates present in the glasses. The crystals which grow during weathering action are alkali metadisilicates in general. The degree of weathering action seems to be determined by the percentage of alkali silicates present. The K-silicates suffer from weathering action much more than Na-silicates. These results confirm T.'s view that the flint glasses are mutual solutions of alkali metadisilicates, lead metadisilicates, and silica. (*C. A.*)

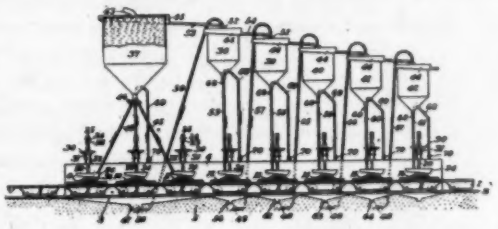
Judging the quality of flint glasses by the method of surface devitrification. K. TABATA, K. YEGAMI, AND S. MORIYASU. *Researches Electro-Tech. Lab., Japan*, No. 182, 19 pp.(1926).—The boundary lines of devitrification of alkali lead silicates whose chemical compositions are $(1-x)Na_2O \cdot x\,K_2O \cdot zPbO \cdot ySiO_2$ are expressed by $y=mx+k$; $\tan\theta=m=4$; $y=4x+2.5z+2.25$. Flint glasses are mutual solutions of $R_2O \cdot 2SiO_2 \cdot PbO \cdot 2SiO_2$ and SiO_2; the chemical formula of the alkali lead silicates may be written as $(1-x)\ (Na_2O \cdot 2SiO_2)\ x\ (K_2O \cdot 2SiO_2) \cdot z(PbO \cdot 2SiO) \cdot w(SiO_2)$. The saturation lines of silica dissolution are expressed by $w=4x+0.5z+0.25$. This equation is convenient for use in graphical expression. For any flint glasses of known percentage compositions, the degrees of devitrification are easily calculated or are obtained by graphical expressions. Some results on flint glasses used as radio bulbs show good agreement with the calculated values. (*C. A.*)

Determination of boric acid in silicates. R. SCHMIDT. *Sprechsaal*, **59**, 541–43 (1926); *Chem. Zentr.*, II, 2010(1926).—Hydrochloric acid is added to an alkaline borate solution after the complete removal of the silica, in the presence of methyl orange as an indicator, until the solution is red; the boric acid can then be determined in the usual way, after the addition of glycerin, by titration with caustic soda with phenolphthalein as an indicator. (*Brit.C. A.*)

PATENTS

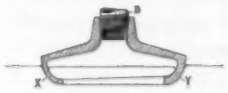
Process of and apparatus for rolling glass. E. B. LE MARE. U.S. 1,622,040, March 22, 1927. Process for producing a continuous strip of glass in which molten glass is rolled into a strip which issues from the rolling apparatus in a direction inclined to the horizontal and is deflected into an approximately horizontal and flat position by tractive force applied to the strip only after it has "set", the strip being supported before it has "set" in the flat and approximately horizontal position.

Method and apparatus for grinding glass. J. W. CRUIKSHANK. U. S. 1,622,091, March 22, 1927. The method of grinding glass, which consists in successively moving the glass under a series of grinders, flowing abrasive in water through a series of grading compartments and successively separating coarse and fine abrasive in each compartment, supplying abrasive from successive compartments to successive grinders, and flowing the used abrasive from each grinder into the next succeeding grading compartment.



Glass-tank construction. JOHN ROTHERAM AND A. E. EVANS. U. S. 1,622,346, March 29, 1927. The combination with a tank adapted to carry a bath of molten glass, and rolling means at one side thereof for forming a sheet or ribbon of glass, of a clay outlet member imtermediate the glass bath and the rolling means provided with an outlet slot for conducting the glass to the rolling means, a pair of hollow metal beams extending along the upper and lower edges of the outlet member and adapted to support such member, and means for circulating a cooling fluid through the beams. In combination with a tank adapted to carry a bath of molten glass and having a drawing extension or forehearth at its front end of less height than the body of the tank, and rolling means at one side for forming a sheet or ribbon of glass, or a removable clay outlet member intermediate the end of the forehearth and the rolling means provided with an outlet slot and constituting the upper portion of the front wall of the forehearth, and a removable roof member for the forehearth to the rear of the outlet member extending transversely of the forehearth, and comprising a metal frame with downwardly projecting inclined end members, and a set of wedge shape refractory blocks fitting against the lower side of the frame and supported therein by reason of their wedge shape and the engagement of the end blocks with the inclined end members.

Apparatus for handling glass sheets. H. K. HITCHCOCK. U. S. 1,622,380, March 29, 1927. In combination in apparatus for moving glass sheets to and from a surfacing table and inverting them, which consists of a vacuum frame mounted above the table for vertical movement toward and from the table and for movement around a horizontal axis to invert the frame, power means for moving the frame vertically, and automatic means operated by said power means for causing the vacuum frame to rotate about the axis to bring it to inverted position when the frame has moved upward a predetermined distance.

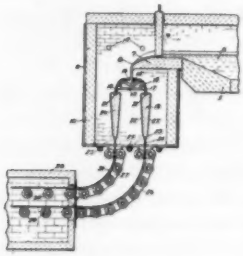


Glass drawing and apparatus therefor. W. E. BUZBY. U. S. 1,622,417, March 29, 1927. In the art of drawing glass cylinders, the method of compensating non-uniformity of temperature conditions of the surface of the bath which comprises the immersion, in the surface of the bath, of a bait arranged so as to initially chill a hotter portion of the bath more than a cooler portion of the bath.

Apparatus for annealing glassware. VERGIL MULHOLLAND. U. S. 1,622,663, March 29, 1927. Apparatus for annealing glassware comprising a tunnel having a ribbed floor, and a conveyer extending through the tunnel and supported by the ribs of the floor.

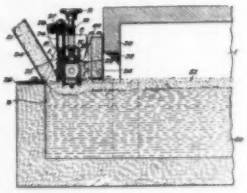
Apparatus for feeding molten glass. K. E. PEILER. U. S. 1,622,666, March 29, 1927. The combination with a receptacle for molten glass having a discharge nozzle, of a removable heater unit comprising a refractory support surrounding the nozzle and spaced therefrom, electrical heating means mounted on the support, and a casing surrounding the support, the casing being detachable to permit removal of the heater unit.

Method and apparatus for producing a continuous strip of glass. F. B. WALDRON. U. S. 1,622,817, March 29, 1927. In apparatus for producing a continuous strip of glass comprising a bed adjacent to which the glass passes, means operative to prevent the glass coming into contact with the bed, consisting of a layer of air in motion between the glass and bed through which the latter air is supplied and mainly removed.



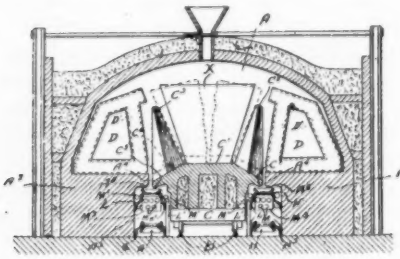
Multiple-sheet-flowing apparatus. FRANK FRASER. U. S. 1,623,051, April 5, 1927. In sheet glass apparatus, means to create a downwardly moving flow of molten glass, and means to separate the flow to produce a plurality of sheets of glass.

Batch feeding to glass tanks. C. B. KINGSLEY. U. S. 1,623,057, April 5, 1927. In combination with a glass melting tank means for the continuous feeding of mix to the tank and means for impelling the new mix into the body of molten glass already in the tank.



Heat-resisting glass. R. F. BRENNER. U. S. 1,623,301. April 5, 1927. A heat resisting glass containing silica, boric oxide, an alkali oxide and aluminum oxide, the latter being in colloidal condition.

Means for forming and delivering charges of molten glass. J. F. RULE. U. S. 1,623,362, April 5, 1927. The combination of means for forming, suspending, severing and dropping a gob of molten glass, and automatic means to engage the gob and move downward therewith at substantially the same speed as the latter would fall under the influence of gravity and shape the gob during the downward movement, the shaping means also having a forward movement in a horizontal direction during such shaping, whereby the gob is given a combined downward and forward movement.



Kiln for glass melting and like purposes. G. E. CRAWFORD. U. S. 1,623,779, April 5, 1927. In a kiln comprising an elongated kiln chamber and a movable hearth separated from a portion of the kiln structure at one side of the hearth by a clearance space, the improvements which consist in a conveyer beneath and running longitudinally of the space and adapted to receive material passing downwardly through the space. In a tunnel kiln comprising an elongated kiln chamber and a movable hearth separated from a portion of the kiln structure at the side of the hearth by a clearance space, the improvement which

consists in mechanism comprising movable material engaging parts located in the kiln chamber below the space for collecting and removing material passing downwardly through the space.

Vacuum flasks. Brit. Pat. 240,061, Feb. 9, 1925; *Illus. Official Jour.* Pat. No. 1921, Nov. 11, 1925.—Relates to the method of production of vacuum flasks in which the outer vessel, is blown to shape and after detachment from the blowpipe, the neck is sealed off and allowed to sink inward, the sunk portion being afterward expanded to form the inner vessel. According to the present invention, the sunk portion, before being expanded, is filled with molten glass sufficient to form the inner vessel. (*Jour. Soc. Glass Tech. Abs.*)

Low-expansion glass. Soc. la Radiotechnique. Eng. Pat. 258,872, Sept. 21, 1926. Glass fusible with difficulty and having a low coefficient of expansion contains a high proportion, but preferably less than 70% of silica, the remainder being a mixture of boric and sodium oxides in the ratio of 85:15. (*Brit. C. A.*)

Heavy Clay Products

The elimination of lamination in clay bars. A. F. Greaves-Walker. *Jour. Amer. Ceram. Soc.*, **10** [4], 309–15 (1927).—The cause of lamination and methods of reducing or eliminating it are discussed. Lamination in stiff-mud clay bars may be caused by either auger or die, or both, or may be due to physical properties of the clay. Each clay is an individual problem. Trouble may be partially or wholly eliminated by varying auger distance, changing type of barrel, taper of die, length of die, changing speed of column, proper lubrication, and other means.

On the nature of the influence of humidity changes upon the composition of building materials. Jas. W. McBain and John Ferguson. *Jour. Phys. Chem.*, **31** [4], 562–94 (1927).—After an extensive study of water "sorption" by various building materials, M. and F. group these substances into 3 groups: (1) Those which sorb either practically no water from water vapor in air or else sorb a very small quantity. This amount remains practically constant for all varying humidities. (2) Building materials which sorb less than 1% of water vapor from air, but with which this small amount varies with the humidity. (3) Those which sorb a large amount of water (10% or more), at high humidity and in which the amount sorbed varies greatly with humidity conditions. The first group includes pure quartz, pure limestones, hard fired brick, and granite. Second group includes ordinary building stone, the artificial sand-lime brick, and various sand stones. Third group includes for the most part various forms of amorphous silica such as kieselguhr, filter cel, gatton stone, calcareous hydraulic cements, etc. Authors show further that certain building stones are exempt from disintegration action due to this particular cause, fluctuating humidity. After being heated to 850°C sandstone loses its power of sorbing water vapor. L.A.P.

Brick in engineering and architecture. L. B. Lent. *Eng. News Rec.*, **98** [13], 535 (1927).—Abstract of paper given by L. at C. B. M. A. Meeting, Chicago. Points out lamentable lack of engineering data on brickwork and discusses present research work being carried on at present by U. S. Bureau of Standards, bringing out the great value of this work to engineers as affecting present building codes. R.A.H.

Physical properties of heavy clays. Anon. Bur. Stand., *Tech. News Bull.*, No. 119, 3–4 (1927).—11 shales and 8 alluvial clays are included in the first phase of an investigation on the determination of the properties characteristic of the types of clays employed in the heavy-clay industries. Preliminary experiments made to show which of several different methods would be most desirable to use in making the various test pieces. R.A.H.

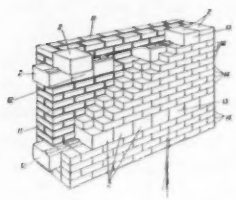
Ancient brick paving. ANON. *Clay-Worker*, **87** [4], 285–87 (1927).—Some interesting facts about the durability of well-fired clay brick and its long usage are presented. F.P.H.

Factory design and equipment. T. W. GARVE. *Clay-Worker*, **87** [4], 290–93 (1927). —The second of a series of articles on this subject. (See *Ceram. Abs.*, **6** [5], 175 (1926).— This article deals with general factory arrangements and handling and storing of raw materials. F.P.H.

Suppose you are firing your first brick kiln. LAWSON VAN ORMER. *Brick Clay Rec.*, **70** [6], 460–63 (1927).—Directions are given for firing a round downdraft type of kiln. Precautions to be taken during the different periods of firing are given. The pyrometer is valuable in setting up a schedule and saving time in the early part of the firing, but is not to be relied on for finishing temperatures due to the variation on different kilns and under different conditions. The trial piece is the only thing which will tell one what is actually going on inside the kiln, and the success of most of the firings will depend largely upon one's ability to understand what it has to tell. A firing chart showing the time and temperature, at which (1) the watersmoking is complete, (2) oxidation is complete, (3) shrinkage starts, for a typical firing is given. The flashing of brick is described. F.P.H.

Efflorescence and capillary fissures in cement mortars. ANON. *Ind. Cemento*, **23**, 67–68; *Rock Products*, **30** [3], 83 (1927).—Efflorescence is caused either by underburned cement which contains particles of uncalcined carbonate or by the hydration and subsequent carbonation of the excess lime set free during setting of over-limed cements. In the first case, calcium carbonate being lighter comes to the surface and in the presence of moisture and air containing CO_2 is converted to the soluble bicarbonate. The bicarbonate easily reverts to the insoluble calcium carbonate and this precipitates on the cement surface, giving it a streaky white coloration. During the setting of high-lime cements the excess lime hydrate is set free and converted through the action of CO_2 and water into the soluble calcium bicarbonate. This bicarbonate comes to the surface and is changed to the insoluble carbonate. The resulting white appearance of the cement surface is called efflorescence. Capillary cracks are only superficial and do not indicate an unsound concrete. They may be avoided by using mortars that are not too rich and exercising precaution in the selection of mixing water. The concrete should be covered and kept in a humid condition, the surface being sprinkled to retard the setting of the upper cement layer. F.P.H.

Standardization of brick sizes. ANON. *Ind. Canada*, **27**, 88 (1927).—The Engineering Standards Assn. was requested by the Canadian National Clay Products Assn. to coöperate in a movement to make effective a resolution passed by the latter Association, *viz.*: standardizing brick sizes: common brick 8 by $2\frac{1}{4}$ by $3\frac{3}{4}$; rough face brick 8 by $2\frac{1}{4}$ by $3\frac{3}{4}$; smooth face brick 8 by $2\frac{1}{4}$ by $3\frac{7}{8}$, the sizes recommended by the Division of Simplified Practice in the U. S. and generally accepted by construction interests. Arrangements are now being made by the Association to have the resolution made at the conference officially approved by all interests, and the Association committee will then prepare a specification which will be submitted for approval of the main committee of the Association for publication and circulation among all the construction, technical, and manufacturing interests involved. O.P.R.O.



PATENT

Fire-receiving wall. L. S. ABBOTT. U. S. 1,624,200, April 12, 1927. A composite wall of the character described consisting of 2 sections, an outer section made of bricklike elements to constitute the weight supporting section, an inner section made of bricklike elements of refractory material, and refractory means arranged at intervals throughout the height of the wall

to form a cross-tie between the sections, the means consisting of rows of complementary brick-like elements, one row anchored in the outer section of the wall and the other forming part of the inner section of the wall, the complementary brick elements of the rows being arranged one above the other and the rows each having interlocking projections and recesses coöperating with recesses and projections in the other row where the 2 rows are juxtaposed, the complementary elements forming a shelf to support the superposed refractory elements constituting the inner section.

Refractories

The effect of steam on the transverse strength of fireclay bricks. C. W. PARMELEE AND A. E. R. WESTMAN. *Jour. Amer. Ceram. Soc.*, **10** [4], 292–98 (1927).—In connection with an investigation of checker brick for carbureters of water-gas machines, it was considered desirable to find out whether or not fireclay brick suffered an appreciable decrease in transverse strength when exposed to the action of steam at a high temperature. Except for occasional references to the "destructive action" of steam, no information on this score was found in the literature. This paper describes experiments in which standard straight bricks at 1100°C were subjected to the action of steam at the same temperature and the resulting change in transverse strength measured. No significant decrease in strength due to the action of steam alone was found.

The use of super-refractories as checker brick in gas manufacture. H. J. KNOLLMAN. *Jour. Amer. Ceram. Soc.*, **10** [4], 299–308 (1927).—During the past year, Carbofrax and Diamel brick, each having distinctly different but superior heat-transfer properties as compared with fire brick, were tried out as part of the regular checker brick in a full-sized standard single-shell oil-gas generator, which was operated under normal conditions. It was hoped that increased gas-generating capacity would be obtained by their use, but such was not the case, chiefly because of the influence of other factors having as much bearing on generator capacity as the checker brick. The chief limiting factors were (1) the remoteness of a large portion of the checker brick from the combustion chamber and therefore from the source of heat supply; (2) uneven heat distribution in the generator; and (3) the formation of heavy cokelike carbon deposits on a portion of the checker brick. With the development of improvements in the generators and the correction of some of these difficulties, there appear to be excellent possibilities in the use of brick of superior heat-transfer properties in promoting operating efficiencies and in increasing gas production.

Temperatures in powdered coal furnaces having extended radiant heat absorbing surfaces. RALPH A. SHERMAN. *Mech. Eng.*, **49** [4], 335 (1927).—This is a report of an investigation of the proper application of boiler-furnace refractories being conducted by the Bureau of Mines in coöperation with the Special Research Committee in Boiler-Furnace Refractories of the American Society of Mechanical Engineers. Temperatures have been measured in a number of furnaces equipped with extended radiant heat absorbing surfaces and various types of powdered coal burners. C.J.H.

A note on the X-ray patterns of mullite and sillimanite. J. F. HYSLOP AND H. P. ROOKSBY. *Jour. Soc. Glass Tech.*, **10** [40], 412–16 (1926).—H. and R. give data on spacing of lines in X-ray patterns of sillimanite and mullite sufficient for their differentiation. Clays fired as low as 1200°C show evidence of presence of mullite. D.J.McS.

Some uses of commercial sillimanite in glass works. A. COUSEN AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **10** [40], 416–24 (1926).—Sillimanite refractories very successful for sieges of pot furnaces, also for boots and skimmer blocks. Good results obtained with sillimanite refractories for burner blocks. Results with pots of

this material generally good, but increased cost over clay refractory limits its use for this purpose. Irregular results obtained with tank block made of sillimanite refractory. Necessity of high temperature firing of these refractories emphasized. D.J.McS.

Requirements of refractories for manufactured-gas plants. SANDFORD S. COLE. *Fuels and Fur.*, **5** [3], 345–46 (1927).—The use of silica in the construction of the regenerators and ovens has been one of the outstanding factors in the advancement of the by-product coke oven to its present state. C. describes the advantages of silica, the types of silica bricks which are used, the specifications which they should meet and the precautions which should be observed in their use. C. also discusses the use of fire brick in the regenerators, the properties they should possess and the conditions they have to meet. The importance of heat insulation and of periodical inspection and testing is pointed out. A.E.R.W.

Properties and service of glass-melting pots. DONALD W. ROSS. *Fuels and Fur.*, **5** [3], 375–76 (1927).—Clay glass pots may be termed the most difficult ceramic product. R. describes the manufacture and use of glass pots and tells how certain variations in the manufacturing procedure and raw materials may be expected to affect the service rendered by the pots. In the future it may be expected that relatively thin-walled dense pots will be developed that will have sufficient strength and better heat transfer properties. A.E.R.W.

The influence of blast-furnace dust on the cone fusion point of clay material with various alumina contents. FRITZ ILLGEN. *Ber. deut. keram. Ges.*, **7** [1], 32–36 (1926). —An investigation is made on the effect of blast furnace dust on clay refractories of varying alumina content. The blast furnace dust had the following analysis: Alkalis 11.98%, FeO .52%, F_2O_3 1.63%, SiO_2 28.4%, MnO 2.36%, MgO 8.6%, SO_3 4.73%, CaO 10.01%, Al_2O_3 11.76%, CaS 5.78%, Pb .6% Zn 11.97%. Six refractories were used in the investigation varying from 43% Al_2O_3 to 26% Al_2O_3. A series of cones were made up for each refractory using varying amounts of this blast furnace dust. Those refractories of higher alumina content had consistently the higher fusion point as the amount of dust was increased. These fusion points ranged from 1750°C for the most refractory brick to 1100°C for the mixtures of 50% clay and 50% dust. It is concluded that it is best to use refractory brick of moderately high alumina content in the upper zones of the hot-blast stove used with the blast furnace. In the lower zones of the stove the brick with lower alumina content may be used. F.P.H.

Factors affecting open hearth refractories. B. M. LARSEN AND A. GRODNER. *Blast Fur. Steel Plant*, **15** [4], 161–64 (1927).—Certain relations between refractories, service, insulation, and flow of heat in the open-hearth furnace are given. The investigation was conducted under operating conditions and further checked in the laboratory. Temperature gradient curves for various parts of the refractories used in the open-hearth furnace are given. F.P.H.

Refractory bricks. ANON. *Continental Met. Chem. Eng.*, **1**, 155 (1926).—Refractory bricks are said to be very effectively protected against the corrosive influences of the furnace atmosphere by washing with "zirkallit," a preparation consisting mainly of zirconium earth. The melting point of this material lies above 1800°C, while the sintering point is, by the addition of certain components, reduced to about red heat, so that bricks are covered with a dense and indestructible protective layer possessing a very low coefficient of expansion. Practical tests carried through at the Staatliche Porzellan-Manufaktur, Berlin, have yielded very good results. O.P.R.O.

The Ceramic Society. ANON. *Pottery Gaz.*, **52** [598], 661–64 (1927).—"Refractories for the Pottery Industry, Part II" was read by Walter Emery at the March meeting. The following details were taken up: sagger requirements; effect of erratic grinding; local

marls; improved methods of "clay-getting;" mixing the clays; control of grinding and choice of grog; refractoriness reduced by glost grog; effect of stress; mixing of clay and grog; making saggers; drying and "green" firing; and the advocation of a more uniform heat treatment. E.J.V.

Occurrence and significance of alkali cyanides in the iron blast furnace. S. P. KINNEY AND E. W. GUERNSEY. U. S. Bureau of Mines, *Tech. Paper* No. 390. Price 10 c. H.H.S.

The thermal conductivity of vitreous silica, with a note on crystalline quartz. G. W. C. KAYE AND W. F. HIGGINS. *Proc. Roy. Soc.* (London), **A113,** 335–51 (1926).—The thermal conductivity of vitreous silica was determined at temperatures from 60° to 240° by a "divided bar" method. The results do not agree with Eucken or Barratt. The conductivity increment per degree is of the same order as that of Barratt. (*C. A.*)

Relining smelting furnaces. V. WEINOD. *Metal Ind.*, **29,** 273–74 (1926).—A few notes on the repair of furnaces, the destructive agents which the brickwork must withstand, and the design of the structure of the furnace. (*Jour. Iron Steel Inst.*)

Service conditions of refractories for open-hearth steel furnaces. Carnegie Inst. Tech., Bull. No. 23 of Mining and Metallurgical Investigations: *Foundary Trade Jour.*, **33,** 468 (1926).—The results are presented of a study of the conditions of service which affect the use and wear of refractory materials used in the construction of open-hearth furnaces. (*Jour. Iron Steel Inst.*)

New furnace lining. R. WALKER. *Iron Age*, **118,** 420 (1926).—The application of monolithic lining to an oil-fired annealing furnace is described. (*Jour. Iron Steel Inst.*)

Fireclay bricks. E. R. THEWS. *Foundry Trade Jour.*, **33,** 339–41 (1926).—A discussion of the properties of fireclay bricks and their requirements for metallurgical furnaces. Of all the refractories commonly used, fireclay bricks are least subject to change of volume and shape under actual working conditions. Well-fired fireclay bricks of good quality are subject only to normal coefficient of expansion amounting to 0.59×10^{-5}. (*Jour. Iron Steel Inst.*)

Refractories in the foundry. H. V. GRUNDY AND A. PHILLIPS. *Foundry Trade Jour.*, **33,** 387–91, 445–48 (1926).—A discussion of the methods of testing and characteristics of molding sands, blackings, and facings. The properties of fire brick used in cupola construction and the action of slag on cupola linings are also dealt with. (*Jour. Iron Steel Inst.*)

An investigation of the premature failure of combustion chamber material. A. J. DALE. *Gas Jour.*, **175,** 862–65 (1926).—A report of a research conducted by the British Refractories Research Association. The refractory contained a silica content of 88% and a considerable amount of free quartz, and it is suggested that such fine-grained, friable material needed special care during the preliminary heating up. (*Jour. Iron Steel Inst.*)

Silica refractories for the iron and steel industries. W. HUGILL AND W. J. REES. *Bull. Brit. Refrac. Research Assn.*, No. 12, 170–86 (1926).—Chemical composition, texture, mineralogical composition, thermal characteristics, mechanical properties, and storage of silica bricks are discussed. The changes in composition and structure during use are also dealt with. (*Jour. Iron Steel Inst.*)

Silica brick problems. C. P. WILLIAMS AND C. S. GRAHAM. *Proc. Lincolnshire Iron and Steel Inst.*, **1,** 63–88 (1918–20).—The paper gives a résumé of the work carried out by the authors on the testing of bricks. (*Jour. Iron Steel Inst.*)

Note of the flaking of refractory bricks. P. GILARD. *Rev. universelle Mines*, **9,** 81–89 (1926).—G. shows that the flaking of bricks is governed by 3 principal factors:

thermal diffusion, expansion, and flexibility or maximum deformation under shear strain. There are other causes as well, such as the dilatation of quartz due to heat even in a uniformly heated brick. The remedy for minimizing the flaking of the bricks lies in the method of manufacture, and G. points out some of the ways in which this may be effected, such as by increasing the grain-size of the lean materials and reducing the amount of plastic matter, and by a preliminary firing of part of the clay.

(*Jour. Iron Steel Inst.*)

The testing and behavior of refractory material under stress at high temperatures. A. J. DALE. *Bull. Brit. Refrac. Research Assn.*, No. 12, 94–113 (1926).—Previous work by D. and others on the behavior of different types of refractory materials under stress at high temperatures is summarized. Typical load-test results provided by silica and firebrick materials differing widely in chemical, physical, and mineralogical constitution, are presented, and the industrial interpretations of these results are suggested.

(*Jour. Iron Steel Inst.*)

The spalling of refractory materials. A. T. GREEN AND A. J. DALE. *Bull. Brit. Refrac. Research Assn.*, No. 12, 127–69 (1926).—A review of the work of previous investigators on the spalling and disintegration of refractories. A bibliography of the literature is appended. (*Jour. Iron Steel Inst.*)

The thermal properties of refractory materials and a consideration of the factors influencing them. A. T. GREEN. *Bull. Brit. Refrac. Research Assn.*, No. 12, 26–50 (1926).—A survey of the work of different investigators on thermal properties of refractory materials, including specific heat, heat capacity, temperature diffusivity, thermal conductivity, and emissivity. A bibliography of the literature on the subject is appended. (*Jour. Iron Steel Inst.*).

The testing of refractory material for resistance to slag corrosion and erosion. A. J. DALE. *Bull. Brit. Refrac. Research Assn.*, No. 12, pp. 114–26 (1926).—A review of the work of previous investigators. (*Jour. Iron Steel Inst.*)

Corrosion of steel furnace refractories. A. SCOTT. *Bull. Brit. Refrac. Research Assn.*, No. 12, 60–71 (1926).—The normal types of refractory materials used in steel furnaces are described. Two main types are met with: the first depends on the surface reactions which ensue between the corrosive agent, metal, slag, or dust, and the materials of the refractory. The 2nd is concerned with the penetration of the refractory by such agents and the physical disintegration which follows such penetration, the former effect invariably accompanying the latter. Other failures may be due to local overheating or to defects or weaknesses in the materials used. (*Jour. Iron Steel Inst.*)

Cement base refractory materials. J. DAUTREBANDE. *Chaleur et Ind.*, No. 70, pp. 75–76 (1926).—Refractories with a clay base and carrying 30 to 40% of alumina have not proved satisfactory at very high temperatures. The alumina was increased to 50 and even 80%, but the resulting materials were then very expensive. Cement agglomerates, made of a mixture of unground burnt cement and clinkers were tried and gave very good results, besides being much cheaper. The manufacture of bricks and concrete of this material is described. (*Jour. Iron Steel Inst.*)

The Torkret process in iron and steel works. A. SCHMITZ. *Stahl u. Eisen*, **46**, 13–16 (1926).—The Torkret process offers a new method for the lining of furnaces, cupolas, or ladles, without the necessity of molding or ramming the material; the apparatus used is known as a cement gun. The refractory material, in pulverized form, is fed dry into a chamber, whence it is blown by compressed air through a hose. A supply of water is brought through a separate small hose, and led into the nozzle of the larger hose conveying the stream of powdered refractory. The mass becomes intimately mixed and is sprayed on to the wall of the vessel it is desired to coat. The air pressure necessary

for successful working is from 2½ to 3½ atmospheres, and the water pressure must be slightly higher than the air pressure in order to penetrate the mass. The stream of dry powder can be conveyed through the hose over distances up to 250 m. and to a height of 50 m. The material is ground to a size of 0 to 3 mm; if it is used in too fine a state the water does not mix regularly and the mass may be too wet and then too dry. Brick-lined ladles can be coated after cleaning and washing out, the usual practice being to turn them on their side and fill out the worn places first by "torcreting," and then spray the surface evenly to a thickness of about 1¼ inches. A very considerable saving results in the life of ladle linings. (*Jour. Iron Steel Inst.*)

Some experiences with salty coal and brick corrosion. F. C. BISHOP. Paper read before the Coke-Oven Managers' Association, Feb. 18, 1926. (*Jour. Iron Steel Inst.*)

The testing of refractory materials. A. GROUNDS. *Fuel Economist*, **1**, 219–22 (1926).—An illustrated description is given of the Atom testing machine, which can be used for determining the softening points of refractory materials. By means of automatic mechanism, it can also be made to record graphically the thermal expansion before the softening point is reached, and the subsequent contraction. (*Jour. Iron Steel Inst.*)

Fireclay refractories. J. F. HYSLOP. *Royal Tech. Coll. Metallurgical Club Jour.*, No. 5, pp. 31–32 (1926). (*Jour. Iron Steel Inst.*)

PATENTS

Process of drying tank blocks. T. H. RHOADS. U. S. 1,622,051, March 22, 1927. The process herein described of drying tank blocks of clay and like objects, the process consisting in forming a block of clay, or like material, covering the block with burlap, coating the burlap with plaster of Paris to form a jacket therefor, and finally subjecting the block, thus prepared, to heated air in circulation.

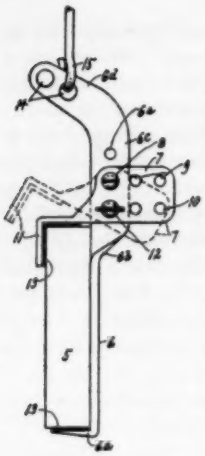
Refractory magnesite composition. Austrian Pat. 103,718; *Rock Products*, **30** [1], 79 (1927).—Magnesite is calcined to caustic magnesia, hydrated and ground 190-mesh fineness. After briqueting it is sintered at a temperature not exceeding 1700°C and then crushed and ground. The product is mixed with 5% to 10% of the unsintered magnesia and alumina, starch, tar or similar substance added and the mass molded into desired blocks. F.P.H.

Refractory cement. Ger. Pat. 438,264; *Rock Products*, **30** [7] 80 (1927).—A mixture of 1 to 10 parts of dry, pulverized bauxite, and 2 parts of cement which contains not more than 30% clay. F.P.H.

Terra Cotta

The economic life of molds. W. L. SAMPLE. *Jour. Amer. Ceram. Soc.*, **10** [4], 278–80 (1927).—The economy of long service from solid cast molds is gradually offset by the loss due to excess thickness of the cast piece. An example of this is discussed, substantiated with figures.

Paths and goals of the stoneware industry. FELIX SINGER. *Chem.-Ztg.*, **51**, 61–62 (1927).—The importance of brick, sanitary and drain tile, insulators, refractories, chemical-resisting materials and other ceramic products used in industry is compared with that of "porcelain," and other materials with an esthetic appeal. Many types of ceramic ware are described; the improvements of physical properties are illustrated from test results in 1921 and 1925; and the goals of the industry are put down as (1) improvement in all physical properties, (2) increase in conductivity for heat, decrease in coefficient of expansion under temperature changes, (3) making a denser product, (4) increased resistance to chemicals (especially bases), and (5) raising the melting point and the softening point under pressure. (*C. A.*)



PATENT

Ashlar-setting clamp. D. N. ANGEL. U. S. 1,621,650, March 22, 1927. An ashlar setting device comprising a vertically disposed suspension bar the lower extremity of the bar directed at right angles to engage the lower edge of an ashlar and the adjacent vertical part of the bar adapted to bear against a face of the ashlar, the upper part of the main bar directed angularly from its main vertical part toward the same side as its lower extremity, a vertically and horizontally adjustable member pivotally mounted intermediate the extremities of the bar and having an inverted L-shaped extension adapted to engage the upper edge and adjacent face of the ashlar diagonally opposite to the parts engaged by the lower extremity of the bar, the angular upper end of the bar adapted to be engaged by suitable hoisting means.

White Wares

The effect of various sodium silicates and other electrolytes on clay slips. S. J. MCDOWELL. *Jour. Amer. Ceram. Soc.*, **10** [4], 225–37 (1927).—Attention is drawn to the fact that different brands of sodium silicate vary 250% in their soda to silica ratio. Four silicates with ratios from 1:1.8 to 1:4 were added on a basis of per cent Na_2O to slips of 6 clays commonly used in the whiteware industry. Rate of flow, hydrogen-ion concentration, and settling behavior were studied. Maximum rate of flow was produced in each case while the slip was acid. Those silicates high in silica were the most potent in their effect on rate of flow for a given amount of Na_2O. The effect was also more pronounced than that of NaOH, Na_2CO_3, or silica sol which were used as comparisons. Possible explanations of the mechanism of deflocculation are discussed to explain the results.

The behavior of feldspar and flint with acids and bases. E. W. SCRIPTURE, JR. *Jour. Amer. Ceram. Soc.*, **10** [4], 238–42 (1927).—On addition of acids and bases to fine-ground feldspar or flint, the same phenomena are observed as with clays, *i.e.*, flocculation, deflocculation, and absorption. The effects are less sharp than with clays, the zone of deflocculation covering a wider range of p_H and flocculation occurring at lower p_H (greater acidity). The sensitiveness of flint and feldspar to reagents increases with fineness of grinding.

The particle size distribution of typical feldspars and flints. E. SCHRAMM AND E. W. SCRIPTURE, JR. *Jour. Amer. Ceram. Soc.*, **10** [4], 264–67 (1927).—The results of particle size analyses of a number of commercial feldspars and flints by the sedimentation method are reported. A comparison of batch and continuous grinding is given as well as a study of the progress of ball mill grinding.

Standardization and plant control as applied to body making. F. H. RIDDLE AND ROBERT TWELLS. *Jour. Amer. Ceram. Soc.*, **10** [4], 281–91 (1927).—The variable nature of the raw materials and the intricate methods involved in manufacture make it difficult to secure uniformity in ceramic ware. The elimination of variable factors is helped by adherence to the following rules: (1) Careful analysis of each operation. (2) Development of written standards for each operation, describing the methods and conditions found best. (3) Enforcement of the standards by careful inspection, using accurate tests after each operation to measure the results just obtained. (4) Division of the body as it is made, into homogeneous units or batches, which remain separate

through the rest of the production operations. (5) Complete records readily available covering each step through which a batch passes in production. (6) Strict adherence to standard procedure even though tempted by expediency to somewhat let down the bars. The application of the above principles to body-making at the Champion Porcelain Company is described.

Heat utilization in ceramic plants. OSWALD HELLER. *Ber. deut. keram. Ges.*, **7** [1], 1–18 (1926).—H. discusses methods of utilizing waste heat. A heat flow diagram is given showing the distribution of heat obtained in firing a kiln of china ware. Of the total heat obtained from the fuel 2.5% is taken up by the ware, 26% by the saggers, 27% by the masonry, 12.5% is lost by radiation and conduction. The remaining part of the heat passes into the flue. Part of the heat absorbed by the ware, saggers, masonry, and part of that passing into the flue can be recovered. The total heat passing into the flue amounts to 87.5%; 56.5% of the heat passes into the heat utilization system and 31% of the heat is lost before or after the heat utilization system is functioning; 46% of the heat is recovered by the heat utilization system. The system described by H. is that designed by Bamag-Meguin Co. of Berlin. A special type of drier is described and illustrated by means of charts. Charts and photographs of the system described are given. F.P.H.

The effect of various forms of silicic acid on porcelain bodies. HANS HIRSCH. *Ber. deut. keram. Ges.*, **7** [2], 49–87 (1926).—The following forms of silica were used in this investigation: fine ground quartz, transparent quartz, 3 sands, 3 flints, two sizes of sand separated from kaolin, and grinding sand. A table is given showing the change in specific gravity when these various forms of silica are fired to cone 16. The specific gravity of the raw silica varied from 2.55 to 2.65 and the silica fired at cone 16 varied from 2.23 to 2.65. Three series of bodies were made up using these various forms of silica. The body compositions were 50% clay, 20% feldspar, and 30% quartz. The 3 series were: (1) kaolin-clay series containing Zettlitzer kaolin, Meissner clay, and Norwegian feldspar, and the various forms of silica, (2) kaolin series containing Zettlitzer kaolin feldspar, and various forms of silica, (3) a kaolin clay body containing various kinds of flux. The bodies were fired to cone 16 and the following physical properties determined: shrinkage, porosity, specific gravity, cone deformation point, tensile and compressive strength, translucency, the electrical breakdown potential, and coefficient of expansion. Numerous photomicrographs are presented showing the progress of the solution of quartz and the crystallization of mullite. A discussion of the results by Dr. Rieke is given. F.P.H.

Ivory bodies use more domestic clay. ANON. *Ceram. Ind.*, **8** [4], 428 (1927).—The demand for ivory ware has increased the use of domestic clays. An ivory batch which is said to give a good body is as follows: flint 32, feldspar 16, Florida kaolin 9, Georgia kaolin 16, Hercules ball 15, Kentucky ball 14. F.P.H.

Calcutta Pottery Works (India). S. DEB. *Min. Geol. Inst. India Trans.*, **21**, 43–45 (1926).—Starting with a modest beginning of one kiln in 1903, the works at present covers over 4 acres of land, and the entire factory has been planned on the latest lines, with a laboratory fitted with up-to-date appliances for analysis and testing of raw materials and carrying on researches in new mixtures, glazes, and decorations. Kaolin, the chief raw material is obtained from Pathurghatta; it is washed or levigated, at the site of occurrence and sent to the works by rail; while other raw materials, such as feldspar, quartz, and limestone are obtainable locally. The raw materials are very good in quality and compare favorably with those used in continental and English potteries. The works at present specialize in the manufacture of insulators, druggists and hospital requisites, laboratory porcelain, and accessories for all industrial purposes. (*Jour. Indian Industries and Labour*, **2**, [1], (1922). O.P.R.O.

Edwin M. Knowles China Company to build $500,000 extension at Newell. ANON. *Pottery, Glass, and Brass Salesman*, **35** [7], 27 (1927).—A note regarding erection of 3 Harrop continuous tunnel kilns in place of 9 upright kilns being razed now. This will give a new capacity equivalent to 30 of the old style upright kilns as compared to the present capacity of 21. E.J.V.

Taylor, Smith & Taylor Company awards contracts for new plant, tunnel kilns. ANON. *Pottery, Glass, and Brass Salesman*, **35** [9], 27 (1927).—A new plant for the production of ivory ware is to be built and 2 Harrop tunnel kilns of 3 to be installed are improvements which will increase the capacity of the company from 17 to 27 kilns. The tunnel kilns will have a capacity of approximately 21 of the old upright kilns. E.J.V.

Bleininger, foreseeing that only fittest will survive in general ware pottery competition, shows "way out" to losers. ANON. *Pottery, Glass, and Brass Salesman*, **35** [10], 27 (1927).—Small ceramic plants in the East Liverpool district which have been engaged in the manufacture of dinner, tea, and toilet ware, may soon change their line of products in order to avoid going out of business due to inability to compete with the bigger factories. Research work done on clays found in the locality has been carried on by Dr. Bleininger and, with a little further experimentation, there are great possibilities for decorating art wares and semi-art utility wares which can be made of the local clays. A survey of the clay resources is to be made. E.J.V.

PATENTS

Glazing ceramic bodies. ORQUALIN. Ger. Pat. 432,724, Dec. 5, 1923. A liquid energizing medium is sprayed or otherwise applied to the green body before firing, so that the surface of the body contains more liquid than the interior, the liquid medium consisting of completely soluble salts, while the batch contains only partly soluble salts. (*Brit. C. A.*)

Porcelain crucibles. STAATLICHE PORZELLAN-MANUFAKTUR AND A. KÖNIG. Ger. Pat. 433,376, Feb. 19, 1925. Filtration with the crucibles is expedited by the provision of a flange on the porous bottom, constructed of the same material. (*Brit. C. A.*)

Equipment and Apparatus

Improved pyrometer combines novel features of technical interest. ANON. *Amer. Glass Rev.*, **46** [31], 14 (1927).—A description of the modern development of the total radiation type pyrometer known as the Pyro instrument, made by the Pyrometer Instrument Co., is given, pointing out special features such as the incorporation of the millivoltmeter, thermocouple, and optical system in a single unit. E.J.V.

The high temperature microscope and its significance for glass technologic research. L. C. GLASER. *Glastechn. Ber.*, **4** [5], 161–72 (1926).—Several different types of high temperature microscopes developed and used by different investigators and their applicability to research problems in glass technology are discussed in detail. E.J.V.

Some processes in the manufacture of pottery. ANON. *Pottery Gaz.*, **52** [598], 653–56 (1927).—An illustrated discussion of the processes carried on in the manufacture of pottery. The process of mold making, methods and machines used in the saucer making shop, the details of the casting process, and the aerographing or spraying process are discussed in considerable detail. E.J.V.

An apparatus for volume determinations. B. FROSTERUS AND H. FRAUENFELDER. *Mitt. Internationalen Bodenkundlichen Ges.*, New Series, **1** [1], 1–5 (1925).—The description of an apparatus for the determination of the volume of powdered and massive sub-

stances. The apparatus can be used for the determination of the porosity of ceramic products. F.P.H.

An all-metal high-vacuum pump system. IVOR BUCKHURST AND G. W. C. KAYE. *Nat. Phys. Lab.*, **19**, 275(1926); reprinted from the *Philosophical Mag.*, Vol. 47, 1924. —A 2 stage mercury-vapor system constructed wholly of steel has been devised, which consists of a jet pump and a condensation pump in series. The system requires a fore-vacuum of 4 mm to afford the highest vacua obtainable by a mercury condensation pump. There are no moving parts; vapors are pumped as efficiently as gases; no drying reagents are required; glass work and rubber joints are eliminated. Above 0.03 mm pressure the speed (using Gaede's definition) is constant at 300 cc/sec.; below this pressure the speed increases rapidly to a constant value of 6000 cc/sec. A short résumé of existing vacuum pumps is given. The following approximate speeds are quoted:

	cc/sec.
Gaede rotary oil pump	100–150
Gaede rotary mercury pump	100
Gaede diffusion pump	100
Gaede molecular pump	1400 (max.)
Langmuir condensation pump	3000–4000

Gradation of machine-broken stone. W. T. W. MILLER. *Rock Products*, **30** [6], 56–58(1927).—A study of the percentages of various sizes produced in jaw and gyratory crushers. F.P.H.

Air separation methods used in fine grinding of rock products. EDMUND SHAW. *Rock Products*, **30** [7], 57–59(1927).—A discussion of principles underlying air classification and some of the machines employed. There are three methods of dry fine grinding, namely: (1) processing, (2) grinding with one pass, (3) grinding with air separation of the product. The product of a mill which it is desired to pass through an air separator consists of: (1) sands, fine and coarse, which may be separated by screens easily. These are coarse enough to be completely separated so that they do not contaminate the finished product. They fall with an accelerating velocity almost approaching that of the formula, $v=\sqrt{2gh}$; (2) the finest sands and coarsest dusts which fall with a slowly accelerating velocity; some of these may contaminate the finished product; (3) the true dusts, i.e., below .05 mm diameter which fall at a constant rate according to Stoke's law; (4) cloud forming dusts that fall so slowly that the rate cannot be observed. F.P.H.

Wire cloth for test sieves. (German). ANON. *Tonindustrie-Kalender*, p. 97(1927).— l = width of opening in mm. d = diameter of wire in mm.

$$\frac{l^2}{(l+d)^2}\times 100=36\%$$

Veb no.	No. of meshes per sq. cm	l in mm	d in mm	Web no.	No. of meshes per sq. cm	l in mm	d in mm
4	16	1.5	1.00	20	400	0.300	0.20
5	25	1.2	0.80	24	576	0.25	0.17
6	36	1.02	0.65	30	900	0.20	0.13
8	64	0.75	0.50	40	1600	0.15	0.10
10	100	0.60	0.40	50	2500	0.120	0.08
11	121	0.54	0.37	60	3600	0.102	0.065
12	144	0.49	0.30	70	4900	0.088	0.055
14	196	0.43	0.28	80	6400	0.075	0.050
16	256	0.385	0.25	100	10000	0.060	0.040

F.P.H.

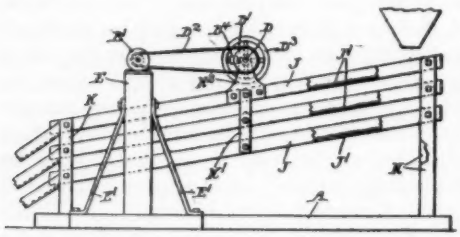
Comparison of French, German, and English sieve numbers. ANON. *Tonindustrie-Kalender*, pp. 84–85(1927).

According to the French custom	According to the German custom	According to the English custom	Meshes to the sq. cm.	According to the French custom	According to the German custom	According to the English custom	Meshes to the sq. cm.
27 mm	26 mm	25.4 mm		27 mm	26 mm	25.4 mm	
no.	no.	no.		no.	no.	no.	
4	3½	3½	2	38	37	36	200
5	4½	4½	3	43	41½	40½	256
6	5½	5½	4	48	47	46	324
7	6½	6½	6	54	52	51	400
8	7½	7½	8	58	56	54½	458
9	8½	8	11	65	62	61	576
15	14	14	30	85	82	80	990
16	15	15	35	101	97	95	1400
21	20	20	60	160	154	150	3505
27	26	25	100	200	192	188	5480
32	31	30	140	250	240	235	8575
				270	260	254	10000

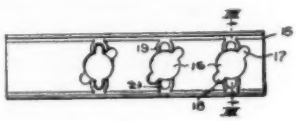
F.P.H.

Some drier considerations. R. S. TROOP. *Bull. Brit. Refrac. Research Assn.*, No. 12, pp. 51–59(1926).—An outline is given of some of the problems involved in obtaining drying schedules, and of methods for the drying of refractories and of molds and cores. Some of the factors which determine the efficiency of the plant and require consideration when installing new driers are discussed. A short bibliography is included. (*Jour. Iron Steel Inst.*)

PATENTS



Screen. JOHN BLAND. U. S. 1,622,305, March 29, 1927. In a screen device, a screen and screen frame including transversely opposite holding parts other than springs for the screen, the holding parts being rigidly mounted and held against longitudinal movement in combination with means for bending and vibrating all of such screen frame whereby the screen is vibrated.



Electric furnace. J. C. WOODSON. U. S. 1,622,621, March 29, 1927. In an electric furnace, in combination, a member of substantially channel section, and a hanger block for supporting a resistor member extending into the member of channel section and held in proper operative position therein by the resistor.

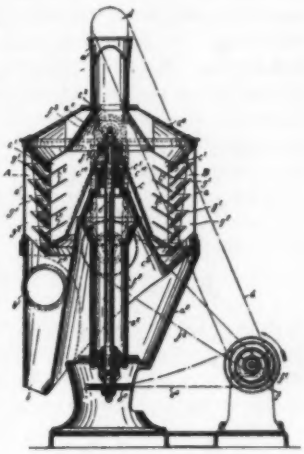
Electric furnace. J. C. WOODSON. U. S. 1,622,622, March 29, 1927. In n electric furnace, in combination, a member of overhung channel section, and an elonga' d hanger block interfitting with the member and extending away from the face there f, and constituting the sole support for a resistor member.

Electric furnace. A. D. KEENE. U. S. 1,622,650, March 29, 1927. In an electi c furnace, the combination with a wall of refractory material and a refractory resisto.- supporting member located in the wall and having a portion projecting into the furnace, the resistor supporting member having a groove therein, of a locking means, interfitting with the groove, for holding the member in the wall.

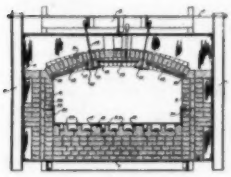
Electric furnace. A. D. KEENE. U. S. 1,622,651, March 29, 1927. In an electric furnace, the combination with a furnace wall, a resistor-supporting member supported by the wall, and a resistor supported by the member, of means for holding the resistor-

supporting member in its proper operative position in the wall, the holding means being prevented from longitudinal movement by the resistor member.

Method and apparatus for grading solid materials. G. R. BAKER, W. E. PRESCOTT, AND C. W. GILDERDALE. U. S. 1,623,040, April 5, 1927. The method of grading particles of solid material by the use of a whirling current of air carrying the particles in suspension, which comprises maintaining said current continuously flowing radially inward from without the whirl, and simultaneously positively whirling the current so as to give to the particles in suspension a centrifugal force acting in a direction opposed to the inward flow of the current.



Electric furnace. FRANK T. COPE. U. S. 1,624,217, April 12, 1927. An electric furnace including a refractory base, a hearth spaced above the base and comprising a plurality of plates having lugs at opposite edges for engagement under the edges of adjoining plates and a resistor mounted in the space between the hearth and base.



Electric furnace. A. D. KEENE. U. S. 1,624,344, April 12, 1927. In an electric furnace, the combination with a wall having an opening therein, of a resistor-unit-supporting member having a portion projecting loosely into the opening, supported by the wall and removable laterally therefrom by an upward arcuate movement.

Kilns, Furnaces, Fuels, and Combustion

A new application of the tunnel kiln. W. D. RICHARDSON. *Fuels and Fur.*, **5** [3], 313–14, 360(1927).—A paper presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Detroit, Michigan, Feb., 1927. To be published by *Jour. Amer. Ceram. Soc.* A.E.R.W.

Brick kilns and their development in 50 years. A. NAWRATH. *Tonind. Ztg.*, **50,** 50th Anniv. No., 30–31 (1927).—60 years ago most of the clay brick were fired in scove kilns and only the larger plants had regular kilns for this purpose. Such kilns are very wasteful in fuel. In 1859 F. Hoffman developed the circular continuous kiln, with which a big saving in fuel was effected. In the Hoffman kiln the fire travels around the kiln, the ware being set in front of the fire and removed in the rear of the same. The air used to cool the fired brick becomes heated in cooling the brick and thus becomes preheated for combustion where it is used. In front of the fire the gases of combustion pass through the unfired ware and heat up the same. For a long time it was difficult to obtain good colored ware in these kilns, and consequently many of the larger companies went back to the old periodic kilns which seemed to give the brick a better color. The Hoffman kiln was at that time only used for common brick with which the color is not of importance. Improvements were made in these kilns and it is now possible to obtain brick with a good color in these. The old circular kilns were abandoned and changes were made to oval and rectangular shapes. In the old kilns the waste heat was passed through the cold unfired brick upon which the moist gases were condensed with a considerable amount of S which produced a scum. This trouble has been overcome by passing the hot air from the cooling chambers into the chambers in which the ware is

being heated up. For a small plant this type of kiln is too large. In 1879 Jacob Bührer developed his zigzag kiln which operates similarly to a continuous kiln but is much smaller, having chambers about 0.9 to 1.5 m. in width. The tunnel kiln was then introduced into the brick industry by Otto Bock. Gas-fired continuous chamber kilns were introduced by Escherich and Mendheim. These kilns are seldom used for brick but are usually used for firing materials which cannot be fired sufficiently high by means of coal firing such as refractories and stoneware. At present a semicontinuous kiln is used for small plants which is promising. It consists of a firing chamber about 8–12 m. long and 3–4 m. wide and is fired at one end and the outlets to the chimney are at the other end. Openings for firing are put at intervals between the ends through which the ware may be fired similar to a continuous kiln. This is used by plants having an annual capacity of 450,000 to 500,000 brick. Heat from the cooling brick is used to heat the newly set brick. H.G.S.

Fineness and structure of pulverized coal. P. ROSIN AND E. RAMMLER. *Power*, **65** [11], 419(1927).—The pulverization of coal is a part of the complete combustion system. The fineness of the pulverization should be increased with low volatile coals and with increased cooling of the furnace walls. Surface area and character of the coal particles are factors in the rate of combustion of powdered coal. C.J.H.

Heat transfer through insulation. L. B. MCMILLAN. *Power*, **65** [5], 180(1927). —Definitions of heat transfer terms are given and formulas worked out for the rate of heat transfer under certain given conditions. The effect of air velocity on heat transfer through insulation is discussed. C.J.H.

Heat transfer through insulation. L. B. MCMILLAN. *Blast Fur. Steel Plant*, **15** [3], 146–51(1927).—A short discussion of the fundamentals of heat conduction with definitions of the terms used is given. Application of formulas is explained by examples. F.P.H.

Heat losses in a periodic kiln. A. E. PHOENIX. *Brick Clay Rec.*, **70** [6], 466–67 (1927).—P. uses the data collected by the Bureau of Mines and published in "The Burning Problems of Industrial Kilns" as a basis for calculating the saving in fuel that would result from insulating the crown of a downdraft kiln. A formula is given for calculating these losses, provided the temperature of the hotter surface, the temperature of the cooler surface, and the conductivities of each material is known. The losses during the 3 periods, water-smoking, oxidation and heating up period, and soaking period are calculated for an insulated crown and an uninsulated crown. The calculated saving in using a properly insulated crown amounted to 2,047 cu. ft. of gas per thousand brick fired in the case selected. A chart is given showing the variation of conductivity with temperature for the following types of brick: (1) silica brick, (2) fire brick, (3) red brick, (4) Sil-O-Cel C-22 brick, (5) Sil-O-Cel super brick. F.P.H.

An efficient round, downdraft kiln for firing refractories. J. B. LYON. *Brick Clay Rec.*, **70** [6], 470–72(1927).—An abstract of a paper presented at the AMERICAN CERAMIC SOCIETY Annual Meeting, Feb., 1927. F.P.H.

Fuel in the clay industry. ANON. *Brick Clay Rec.*, **70** [7], 534–52(1927).—The following fuels are discussed: coal, powdered coal, oil, producer gas, natural gas, and coke-oven gas. The advantage of each type of fuel is pointed out and pointers are given that will enable the operator to get the maximum heating value out of the fuel that he is now using. The qualifications to look for in coal are about as follows: (1) low sulphur content where color is important or with glazed products, (2) nonclinkering if used on flat grates, hard clinkering in dead bottom fire boxes, (3) fine if fired through stoker or in continuous kilns, (4) high heat value, (5) long flame, (6) type of ash, (7) cheapness. A division of ceramic plants manufacturing heavy clay products according to kind of fuel used shows that from 75 to 97% of the plants use coal. A

table showing the comparative heat values of coal, oil, and gas is given. A table showing the approximate and ultimate analysis and heating value of coals mined in the U. S. is given. The proper methods of storing coal are discussed. High and low pressure air systems for oil firing are discussed and compared. A table showing the composition of various coals that are used in making producer gas is given. F.P.H.

Relation of fusibility of coal ash to formation of clinkers. ANON. *Brick Clay Rec.*, **70** [7], 552(1927).—An abstract of a report of results obtained in a coöperative investigation undertaken by the Bureau of Mines and the Carnegie Institute of Technology. The average quantity of clinker formation relative to the total ash in the coal and also the size of the clinker pieces seems to have a fairly definite relation to the softening temperature of the coal ash, as determined by the standard gas-furnace method. This relation is better expressed by using the softening temperature than it is by that of the initial or fluid temperatures. No better relation can be obtained from the softening temperatures of the ash of the float-and-sink portions of the coal separated by fine grinding and using a liquid of 1.35 specific gravity. The clinker formation does not increase materially until the softening temperature of the coal ash is below 2600°F. The 7 coals selected for tests in this investigation included bituminous coals from Ohio and Illinois and semibituminous coals from Pennsylvania and Maryland. F.P.H.

Coal is most important industrial fuel. ANON. *Ceram. Ind.*, **8** [4] 432–35(1927). —A table is given showing the purchasing power of one dollar in terms of B.t.u. from various types of fuel. The fuels are arranged in the following order on the basis of B.t.u./dollar: bituminous coal, anthracite coal, seasoned hardwood, natural gas, city gas, crude oil, and electricity which is the most costly. The best type of coal for firing pottery ware of any kind is a long flame from volatile coals containing less than 1% sulphur. F.P.H.

Gaseous fuels are increasing in industry. ANON. *Ceram. Ind.*, **8** [4], 435–45(1927). —The chief advantage of gaseous fuels is that they are clean and easily controlled. The most desirable coal for producing producer gas should conform to the following specifications: volatile matter 30–50%, fixed carbon 50–60%, ash under 15% with ash fusion temperature of over 2200°F. With low ash content, one pound of coal will make from 60 to 75 cubic feet of gas at 62°F or 120,000 to 140,000 cu. ft. of gas per ton. Where the composition of the coal and its ash allow, a saturation temperature of about 120°F may be used. This means that from .28 to .30 pounds of steam per pound of coal is used. F.P.H.

City gas both valuable and important. H. L. READ. *Ceram. Ind.*, **8** [4], 445–46 (1927).—Some of the advantages of this fuel are: always available, high heat value, requires little storage space, compares favorably with other fuels and its cost can be kept reasonably low. F.P.H.

Liquid fuels afford steady temperatures. ANON. *Ceram. Ind.*, **8** [4], 449–52(1927). —With fuel oil there are no standby losses and it is always available. It leaves no ash and is easily stored. F.P.H.

Fuel oil in enamel and pottery industry. Z. D. BASSETT. *Ceram. Ind.*, **8** [4], 458–60(1927).—Gives advantages of fuel oil over coal. There are several methods of burning oil: the high oil pressure or mechanical system, the compressed air and steam system, and the low pressure air system. The best combination is the low pressure air low pressure oil system, that is, with the oil furnished at 15 to 25 pounds pressure, and the air at from 8 to 12 ounces; the flame developed is fully as hot as the high pressure air flame but furnishes a much more even distribution of heat and does not have the cutting effect; a much closer control of draft is obtained with the low pressure air system. F.P.H.

Powdered coal in German glass field. LUDWIG SPRINGER. *Ceram. Ind.*, **8** [4], 462(1927).—Coal dust as fuel in manufacturing German glass is not favorable for clear glass but is applicable in making dark bottle glass. It is claimed that little saving is realized by the use of this fuel. F.P.H.

A successful application of powdered coal as a tunnel kiln fuel firing hard fired common brick. F. M. HARTFORD. *Clay-Worker*, **87** [4], 309–11(1927); reprinted from *Jour. Amer. Ceram. Soc.*, **9** [10], 684–89(1926); for abstract see *Ceram Abs.*, **6** [1], 17(1927). F.P.H.

Temperatures attained in various industrial kilns. ANON. *Tonindustrie-Kalender*, page 65–66(1927).

Type of kiln for firing	Temp. °C	Seger cone	Type of kiln for firing	Temp. °C	Seger cone
Plaster of Paris	120–180		White	1200–1300	6*a*–10
Keene's cement	900–950	010*a*–07*a*	Roof tile	920–1280	09*a*–9
Dolomite	1100–1300	1–10	Stoneware	1120–1350	2*a*–12
Pyrolignite of lime	1230–1410	7–14	White ware (body firing)	1140–1300	3*a*–10
Janaer tufaceous limestone	1330	10	White ware (glost firing)	900–1200	010*a*–6*a*
Shell limestone	1330	10	Porcelian (bisque firing)	900–1000	010*a*–05*a*
Portland cement	1350–1500	12–17	Porcelain (glost firing)	1300–1530	10–20
Building tile	900–1080	010*a*–01*a*	Chamotte ware	1200–1400	7–14
Clinker	1000–1250	05*a*–8	Silica brick	1300–1400	10–14
Face brick red and yellow	900–1080	010*a*–01*a*	Glass pot furnace	1750	34

F.P.H.

Fuel in 1926. H. J. HODSMAN. *Ann. Rept. Soc. Chem. Ind.*, **11**, 22–48(1926).—The report of the Royal Commission investigating the troubles of the coal trade made recommendations of technical interest. It recommended the institution of a National Fuel and Power Committee, and this has been carried out. It advised an intensification of research, with financial support from the State, and an official system of sampling and analysis of coal so as to encourage the sale of fuel to specification and guarantee. In the future it seems likely that the world will have recourse to coal for liquid fuel. By hydrogenation it is possible to convert 50% of coal into liquid products (Bergius process), but the cost of hydrogenation under pressure is at present forbidding. The alternative is to first gasify the coal and then hydrogenate the CO to methyl alcohol and "synthol." H. then considers the whole subject under the headings: Carbonization, coke oven practice, low-temperature carbonization, coke and its reactivity, steam raising, gasification of coal, gaseous combustion, peat and lignites, constitution of coal, and analysis and testing. H.H.S.

Sulphur in fuel, and its determination. ANON. *Glass Ind.*, **8** [4], 90–91(1927).—The forms in which sulphur is found in coals, its heating value, and its relation to clinkering of the ash are discussed. Two methods of determining sulphur in coal are outlined: (1) Eschka's method, and (2) the sodium peroxide method. E.J.V.

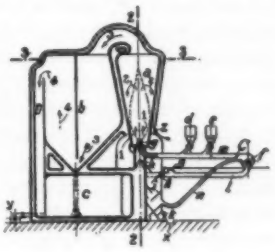
Selection of proper furnace insulation. M. H. MAWHINNEY. *Forging, Stamping, Heat Treating*, **12**, 328–33(1926).—M. discusses the selection of proper insulating material for the various conditions which commonly occur in practice. Each case must be considered as a separate problem, because the correct insulation for one temperature and fuel is by no means correct for other conditions. The economic side of the question is also dealt with, for the insulation must pay for itself by the economies in fuel which it effects; if it does not, then nothing is gained by its use. (*Jour. Iron Steel Inst.*)

The properties of heat-insulating material for high-temperature metallurgical plant. A. T. GREEN. *Bull. Brit. Refrac. Research Assn.*, No. 12, pp. 13–25(1926).—The

essential properties of high-temperature insulating materials are discussed. Although a great number of insulating materials and compositions are on the market the demands of high-temperature insulation can only be met by a few, including slag wool and diatomaceous earth products. The selection of insulating materials cannot be based on insulating efficiency alone. A knowledge of the circumstances of its future use, particularly regarding the face temperature to which it will be subjected, is essential. The following data will serve in the selection of the material: (*a*) the coefficient of thermal conductivity at temperatures between 300 and 800°C; (*b*) percentage porosity, together with a description of the nature of pore spaces; (*c*) refractoriness, together with the temperature at which the material disintegrates; (*d*) crushing strength. One of the most important limiting factors in the use of insulating material is the structural efficiency of the inner wall of the refractory material. (*Jour. Iron Steel Inst.*)

PATENT

Kiln for the firing of cement. CARL NASKE. U. S. 1,622,337, March 29, 1927. In a calcining kiln for cement and the like, a firing and calcining shaft, a single conduit for introducing solid cement material in finely divided condition, air and fuel from below into the bottom thereof, and substantially in an upward direction, means adapted to introduce secondary air into the bottom portion in close vicinity of the material-air-and-fuel introducing means, discharging means communicating with the bottom portion below the fuel-air-and-material introducing means and a settling chamber communicating with the top portion of the shaft.



Geology

Preliminary report on the economic mineral resources of Calhoun County. J. E. LAMAR. Illinois State Geol. Surv., *Rept. of Investigations*, No. 8.—L. describes the geologic structure and stratigraphy and discusses the economic resources including limestone, shales, clay, coal, sand and gravel, phosphates, oil and gas. Preliminary tests of a deposit of gray or white clay, tentatively regarded as tertiary in age, which might possibly be used in the manufacture of moderate duty refractories, stoneware, terra cotta, and sanitary ware are described. More complete tests are reported on a deposit of fire clay beneath No. 2 coal which has been correlated with the Cheltenham clay of the St. Louis district. These indicate that it might be used for the manufacture of architectural terra cotta or face brick. A.E.R.W.

Geology and mineral resources of the Equality-Shawneetown area. CHARLES BUTTS. Illinois State Geol. Surv., *Bull.*, No. 47 (1925).—B. describes the stratigraphy and economic geology which includes coal, limestone, chert for road materials, shale, sand, oil and gas. Shale for brick and cement could doubtless be had in quantity from the Tradewater, Carbondale, and McLeansboro formations. A.E.R.W.

Geology and mineral resources of the Carbondale quadrangle. J. E. LAMAR. Illinois State Geol. Surv., *Bull.* No. 48 (1925).—L. describes the geology and geologic history, gives detailed descriptions of the entire Chester series, discusses the coal, oil and gas possibilities, road materials, agricultural limestone, building stone, shales and clays, water sand, and soils. No deposits of shale are being exploited commercially although there are possibilities in this direction. The clays of the later valley fill in the northern part of the quadrangle might yield a fair grade of brick; the glacial clays are probably not as desirable. A.E.R.W.

Geology and mineral resources of the Joliet quadrangle. D. J. FISHER. Illinois State Geol. Surv., *Bull.*, No. 51(1925).—F. describes the stratigraphy and geologic history, discusses the economic resources of the area including dolomite, sand and gravel, water, clay, marl, peat and muck, boulders, and soils. No clay was being utilized commercially at the time this report was written and future exploitation seemed doubtful. A.E.R.W.

China clays. ANON. *Bull. Imp. Inst.*, **24,** 562–63(1926).—Deposits of china clay of good quality occur in the Albany division, Cape Province, Union of S. Africa; and pure white kaolin is found north of Barberton. Large deposits of first-grade china clay have been found near Cape Town. Large deposits of fire clay of excellent quality and of pottery clays are associated with the coal measures. Fire brick and crucibles are manufactured in quantity near Johannesburg. Domestic pottery is produced south of Pretoria. O.P.R.O.

Kaolin. W. J. WYBERGH. Union of S. Africa, Geol. Surv. Mem., 23(1925).—Economic geology of Sabie and Pilgrim's Rest. A deposit of pure white kaolin which lies south-east of Sabie is being prospected. It is remarkably pure, and in some cases entirely free from quartz or other sand, in others more or less mixed and requiring further washing. The whole deposit, where opened up, consists of alternating beds of pure white kaolin, with more or less sandy kaolin, pure light-yellow kaolin, brown clayey sand, and brown gravel. The quantity is probably very large, with similar deposits in the district. O.P.R.O.

Clays. ANON. Canada Dept. of Interior; Prince Edward Island, Canada, Its Resources and Opportunities, 1926.—Clay at Richmond is reported to be one of the best red firing clays in Canada, from which brick and tile are manufactured. The province further possesses deposits of much fine clay suitable, not only for brick and field tile making, but also for the finer grades of art pottery. O.P.R.O.

Clays. *Bull. Imp. Inst.*, **24,** 758–59(1926).—India has enormous resources in common clay, widely distributed, and has also good clays suitable for production of porcelain and high-class pottery. The principal deposits of china clay investigated are, one in the Central Provinces, and one in Bengal; both these deposits are now being worked. O.P.R.O.

Mineral pigments. ANON. *Bull. Imp. Inst.*, **24,** 787–88(1926).—Oxides of iron of the best quality, barites and green earth, purest white chalk, yellow ocher, red clay, raw sienna, and umber have been rediscovered near Aswan, Egypt. It was from these deposits that the ancient Egyptians took their materials used for painting and dyeing monuments and cloths. Costs of production are low; drying can be effected by heat of the sun; fuel and drying machinery are not required. The colors are used for making oil and water paints, distempers, coloring cement tiles, dyeing paper, making printing inks, and coloring linoleum. (*Mining Jour.*, **Vol. 155**(1926).) O.P.R.O.

Clays. R. G. MCCONNELL. Ontario, Dept. of Mines. *Annual Rept.*, **35,** Pt. 2 (1926).—Lake clays are widely distributed in the lowlands of the Sault Ste. Marie area. These clays are finely laminated, grayish, light-bluish, or reddish in color and usually free from pebbles and boulders; highly plastic as a rule, and when mixed with about 25% sand are well adapted for the manufacture of ordinary brick and tile. Raw materials, conveniently situated are available in practically unlimited quantities. O.P.R.O.

Feldspar. ANON. *Ind. Australian Min. Stand.*, **76,** 712(1926).—Valuable deposits of feldspar are found in several parts of the State, and potteries have been making use of material from Ubini and Londonderry. There are 2 commercial varieties of feldspar, both characterized by their extremely low content of iron, ranging in bulk parcels from the merest trace to a maximum of one tenth of 1%, and are easily obtained in large masses of clean unweathered mineral. O.P.R.O.

Barite. ANON. *Ind. Australian Min. Stand.*, **76,** 712(1926).—White barite has been mined at Cardup and Tenterden, and could be obtained in large quantities as a by-product at the galena lead mines, but would probably require roasting to oxidize the small amount of associated galena. O.P.R.O.

Clays. R. C. WALLACE. Ind. Development Board of Manitoba (1926). The Mineral Industry of Manitoba. Bibliography, 42 pages. O.P.R.O.

Brick, tile, and pottery clays in Nigeria. ANON. *Bull. Imp. Inst.*, **24,** 529(1926). —The results of the trials carried out at the Imperial Institute on 4 clays, (1) dark clay, (2) white clay, (3) gray clay from Obenenu River, and (4) gray mottled clay from Oyivo River, Nigeria, may be summarized as follows: strong white building bricks and tiles can be made without difficulty, either by hand or mechanically, from the white or gray clays of the Obenenu and from the mottled gray clay of the Oyivo Rivers. No preliminary treatment, nor the addition of "grog" is required in these clays. O.P.R.O.

The fifty-eighth annual review and year book number. ANON. *Eng. Mining Jour.*, **123,** No. 4(1927).—This number contains mining and trade information for the year 1926 on Cu, Pb, Zn, Au, Ag, Fe, petroleum, Mn, Ni, chromite, W, Co, Mo, Pt, Hg, As, Sb, Bi, bauxite, Al, Ra, U, V, Cd, Ce, Se, Te, Tl, Ti, Th, Zr, asbestos, mica, graphite, talc, tripoli, diatomite, SiO_2, feldspar, kaolin, gypsum, magnesite, barytes, fluorspar, borates, phosphate rock, nitrates, potash, sulphur, and pyrites. Regional summaries of the mining industry are given and papers on "Milling and Flotation" by C. E. Locke, "Hydrometallurgy" by G. D. Van Arsdale, "Smelting Practice" by E. P. Mathewson, and "Iron and Steel Metallurgy" by James Aston. (*C. A.*)

The kaolin deposits of Silesia. E. PRALLE. *Abhandlungen zur praktischen Geologie und Bergwirtschaftlehre*, **7,** 52(1926).—A description of the origin and geological conditions of the kaolin deposits which occur extensively in Silesia. Chemical analyses of the clays found in the principal deposits are given. (*Jour. Iron Steel Inst.*)

Chemistry and Physics

Hydrogen-ion control in ceramics. W. A. TAYLOR. *Jour. Amer. Ceram. Soc.*, **10** [4], 243–58(1927).—Many technical, as well as nontechnical, men hesitate to use hydrogen-ion control because they feel that its application requires the services of a highly trained chemist. This paper shows, by a simple nontechnical discussion of the subject and by a demonstration of the method of making measurements, that a plant foreman can apply it just as easily and accurately as a trained chemist.

Composition of iron blast furnace slags. R. S. MCCAFFERY, J. F. OESTERLE, AND L. SCHAPIRO. *Fuels and Fur.*, **5** [3], 357–59(1927).—A discussion of the silica-alumina-lime-magnesia system and of graphical methods for representing data concerning equilibria. A.E.R.W.

Aqueous solutions of sodium silicates, heterogeneous equilibria of system: Na_2O: SiO_2:H_2O, at 25°C. R. W. HARMAN. *Jour. Phys. Chem.*, **31** [4], 511–18(1927).—Investigated the ternary system, Na_2O:SiO_2:H_2O at 25°C and graphical results shown. Towards the H_2O:SiO_2 side of the system the solutions became colloidal and invalidate further work. Two compounds only are indicated as stable in solution—$Na_2O \cdot SiO_2$ and $Na_2O \cdot 2SiO_2$. Na_2SiO_3 crystallizes with 9, 6, and 2.5 H_2O, while Na_2SiO_3 crystallizes with $9H_2O$. L.A.P.

Studies on the system lime-alumina-silica. The composition, $8CaO+Al_2O_3+2SiO_2$. W. C. HANSEN, W. DYCKERHOFF, F. W. ASHTON, AND R. H. BOGUE. *Jour. Phys. Chem.*, **31** [4], 607–15 (1927).—Investigated the composition $8CaO+Al_2O_3+2SiO_2$ with the intention of studying the evidence bearing upon the existence of a compound of this composition. Used oxyhydrogen flame for preparing samples and obtained a crystalline phase, different in appearance from the phrases ordinarily found in mixtures of CaO,

Al_2O_3, and SiO_2 heated to temperatures up to 1600°C. By proper heat treatment these preparations can be brought to the equilibrium found to exist in this system by Rankin and Wright. The birefraction, mean refractive index, and X-ray spectrum of this phase are the same as those obtained for $3CaO \cdot SiO_2$. The phase also forms in the composition, $8CaO+Fe_2O_3+2SiO_2$ when treated in the same manner. High magnifications and X-ray spectra of these preparations show them to be nonhomogeneous, containing other crystalline materials. All of the evidence obtained and presented by the authors is opposed to the existence of a ternary compound of the composition, $8CaO \cdot Al_2O_3 \cdot 2SiO_2$ stable in this system. Their evidence is also opposed to the existence of solid solutions of the silicates and aluminates in this part of the system. It is concluded that the fiberlike crystals previously reported by some as $8CaO \cdot Al_2O_3 \cdot 2SiO_2$ are $3CaO \cdot SiO_2$. L.A.P.

Aqueous solutions of sodium silicates, silicate ions, electrometric titrations, diffusion, and colorimetric estimation. R. W. HARMAN. *Jour. Phys. Chem.*, **31** [4], 616–25 (1927).—Electrometric titrations of .1 and .2 normal Na_2SiO_3 with .1 and 1.219 normal HCl and of .2 normal Na_2SiO_3 (1:4), with 10 normal NaOH were carried out. The curves obtained with Na_2SiO_3 and HCl are typical of dibasic acids, thus suggesting H_2SiO_3 as dibasic with salts, $NaHSiO_3$ and Na_2SiO_3. The primary and secondary dissociation constants have been calculated from hydrolysis results and from these electrometric titrations: $K_1=4.2\times10^{-10}$ and $K_2=.51\times10^{-16}$. The amount of crystalloidal silica in ratios 2:1, 1:3, and 1:4 has been compared with that in ratio 1:1 in very dilute solution by means of the colorimetric test with H_2SO_4 and ammonium molybdate. In very dilute solution most of the silica in these ratios is crystalloidal, but increase of concentration and increase of ratio increases the colloidal content. Diffusion experiments through membranes of collodion and parchment paper indicate that most of the silica in ratios 1:1 and 1:2 is diffusible; about $\frac{2}{3}$ of the silica in .3*N* 1:4, and about $\frac{1}{3}$ in 1.0*N* H_2SiO_3 was crystalloidal. H_2SiO_3 is much stronger than hitherto supposed, due no doubt to the fact that when prepared by continuous dialysis, the ionizable and diffusible portion is lost. L.A.P.

Sodium nitrate. ANON. *Continental Met. Chem. Eng.*, **1**, 94 (1926).—Natrium (sodium) nitrosum ($NaNO_2$) in the chemically pure condition consists of 33.33 % sodium, 20.29 % nitrogen, and 46.38 % sodium oxide (Na_2O_3), and 55.07 % nitrous acid anhydride (N_2O_3). It crystallizes in form of colorless, transparent 4-faced prisms, easily soluble in water; merchanted in white lumps and as white crystalline powder. Sodium nitrate is produced: (1) by decomposition of sodium nitrate at high temperatures and separation of the undecomposed salt-peter components by crystallization, (2) by a reducing melting treatment of the nitrite with lead, copper, zinc, galena, pyrite, etc., (3) in Germany and Norway by the action of synthetic nitrous vapors on sodium hydrate, or by electrolysis of sodium nitrate. O.P.R.O.

Kaolin and its thermal changes. K. A. VESTERBERG. *Chem. Zentr.*, **2**, 1553–55 (1925); abstracts from *Ber. deut. keram. Ges.*, **7** [1], 11 (1926). F.P.H.

The modulus of rupture of dried clays as a measure of plasticity. H. KOHL. *Ber. deut. keram. Ges.*, **7** [1], 19–31 (1926).—K. reviews some of the theories on plasticity and methods for measuring this property. Previous investigations have indicated a certain relation between mechanical strength and the bonding strength of clays. The tests were carried out on air-dried specimens of clays and body mixtures. About 10 test pieces were used for each type of clay tested. The addition of alkali greatly increased the strength. Cast samples were more dense than molded. Blue clays gave the highest values, 47 kg/sq. cm. The fine kaolins gave the lowest values, 2.8 kg/sq. cm. The fine kaolins gave values from 2.8 to 7.8 kg/sq. cm. The earthenware bodies varied from 5.2 to 12.4 kg/sq. cm. The porcelain bodies varied from 4 to 8 kg/sq. cm. The sagger bodies

varied from 4 to 12 kg/sq. cm. The results of the modulus of rupture tests were characteristic of the different mixtures used and agreed reasonably well with the working properties as observed in actual practice. F.P.H.

The constitution of kaolin. G. A. KALL. *Ber. deut. keram. Ges.*, **7** [1], 36–38 (1926). A discussion of the various structural formulas that have been suggested for kaolin. F.P.H.

New specific heat apparatus. EZER GRIFFITHS. *Nat. Phys. Lab.*, **19**, 91 (1926); reprinted from *Proc. Phys. Soc. London*, Vol. 33, 1921.—The paper is a description of an apparatus for the determination of the specific heat of materials such as cork, charcoal, etc., which are difficult to deal with by the ordinary methods. The calorimeter is a closed cylinder rotating on a horizontal axis. The heating coil and the thermoelements project into the calorimeter and are maintained stationary. The material under test fills $\frac{3}{4}$ of the colorimeter and is mixed by being carried round by the fins attached to the internal surface. To insure equalization of the temperature, the material is ground to a state of fine subdivision before tests. By reducing the weight of all parts to a minimum, a calorimeter of 4 liters capacity has been constructed whose water equivalent is of the order of 100 gms. The jacket surrounding the calorimeter is made of copper wound with a heating coil. In an experiment the temperature of this jacket is maintained equal to that of the calorimeter, thus eliminating the corrections for heat loss by radiation and convection. F.P.H.

Apparatus for the determination of the heat of evaporation of liquids of high boiling points. J. H. AWBERRY AND EZER GRIFFITHS. *Nat. Phys. Lab.*, **19**, 99 (1926); reprinted from *Proc. Phys. Soc. London*, Vol. 36, 1924.—Two new forms of apparatus for determining the heat of evaporation of liquids of high boiling point are described, and their relative merits briefly discussed. In the one, the determination is made by a measurement of the amount of liquid vaporized for a given energy supply (radiation loss being eliminated by means of a constant temperature jacket), and in the other, the energy given up on condensing by means of a continuous flow calorimeter. The latter is thus a modification of the well-known apparatus of Berthelot, but particular attention has been paid to the avoidance of defects inherent in earlier types of apparatus. The apparatus has been tested by determining with them the heat of evaporation of such liquids as alcohol, water, and aniline, whose heat of evaporation are well known. A brief survey of the earlier work is included, and a number of references given. F.P.H.

The thermal conductivities of metal crystals. I. Bismuth. G. W. C. KAYE AND J. KEITH ROBERTS. *Nat. Phys. Lab.*, **19**, 59 (1926); reprinted from *Proc. Roy. Soc. London*, Series A, Vol. 104, 1923.—Previously all accurate measurements of the thermal conductivity of metals have been made on bars of heterogeneous structure. It was thought desirable to compare the values so obtained with the more fundamental ones given by single crystals. A "plate" apparatus has been developed which makes it possible to measure thermal conductivities as high as 0.02 c.g.s. with an accuracy of about 1%, using specimens 2 cm by 1 cm in area and about 1 or 2 mm in thickness. The thermal conductivities of single crystals of metallic bismuth have been determined in directions parallel and perpendicular to the trigonal axis. The values found at 18°C were, in c.g.s. units:

Thermal conductivity of bismuth parallel to trigonal axis,	0.0159
Thermal conductivity of bismuth perpendicular to trigonal axis,	0.0221
Ratio of conductivities	1.39

If a random distribution of crystals is assumed, these figures give a mean conductivity of 0.0195, which agrees well with the value 0.0193 obtained on bars by Jaeger and Diesselhorst in 1899. F.P.H.

Some modified forms of hygrometers. EZER GRIFFITHS. *Nat. Phys. Lab.*, **19**, 123(1926); reprinted with modification from *Proc. Phys. Soc. London*, Vol. 34, 1922.—The paper describes experiments made with the object of developing suitable apparatus for the measurement of humidity at low temperatures. The three classical methods, (1) wet-and-dry bulb hygrometer, (2) the dew-point apparatus, and (3), the hair hygrometer, were studied and so modified that they could be used in a low-temperature room inaccessible to the observer. The common form of wet-and-dry bulb hygrometer is notoriously unreliable, but the ventilated form is quite satisfactory provided the wind velocity past the bulb exceeds about 3 m per second. A tubular form of wet-and-dry hygrometer was developed with an electric fan for aspiring the air past the bulbs. A continuously recording resistance thermometer type was also made, which had a cam device for rapidly dipping and withdrawing the thermometer bulb at periodic intervals from a reservoir of water. The dew-point apparatus was modified into a form suitable for permanent installation, the cooling of the polished metal surface being affected by pipe connections to the cold brine circulation of the stores. In another form a silver thimble, cooled by the evaporation of ether, was placed at one end of a long aluminum tube and a telescope at the other. By suitable arrangements of mirrors and lamps both the silver surface and the thermometer column were thrown into the field of the telescope. The end containing the thimble was inserted into the enclosure through a circular aperture. The instrument was portable and self-contained. A distant reading type of dew-point apparatus was constructed, in which the formation of dew was indicated by the change of reflecting power of the cooled surface. A beam of heat radiation was reflected from the polished surface and concentrated on to a minute thermopile. The thermojunctions were connected to a pivoted indicator situated at the observation station where the observer controlled the flow of cooling fluid by means of a solenoid valve. The formation of dew resulted in a sharp falling-off of the reflecting power and was indicated by the movement of the pointer of the instrument. The hair hygrometer was studied under a variety of conditions and the changes in the calibration of this type of instrument, caused by exposure to low and high temperature, etc., were determined. A very simple form of distant reading hair hygrometer was developed. In this the clockwork drum of the ordinary recorder was replaced by a tubular rheostat. The pointer was pressed into contact with the drum when a reading of the humidity was desired. The two portions of the resistance winding then constituted the two arms of a Wheatstone bridge. A number of other forms of hygrometers were also studied, notably the one utilizing the heating effect on dry cotton when exposed to a humid atmosphere. A convenient form of apparatus for the calibration of hygrometers over a wide range of humidities is described. It consists essentially of a drum fitted with a heavy glass front making an air-tight joint. The drum contains an electric fan which circulates the air over a dish of desiccating agent. This method of reducing the humidity is more effective than bubbling through strong sulphuric acid and does not produce acid spray. The drying agent can be cut out of communication with the chamber by a ground glass cover operated by a lever projecting out of the drum. F.P.H.

An instrument for use in measuring convected heat. A. H. DAVIS. *Nat. Phys. Lab.*, **19**, 171(1926); reprinted with modification from *Proc. Phys. Soc. London*, Vol. 33, 1921.—The rate at which an air stream carries off heat from a hot body may be determined if the mass flow and temperature rise of the air can be measured. An instrument is therefore described which has been used to measure the distribution both of temperature and of mass flow in air streams. In this instrument a platinum wire functions both as a resistance thermometer and as a hot-wire anemometer compensated for temperature changes in the ambient air. The compensation is satisfactory provided the temperature changes in the air are not so extreme that its thermal properties differ appreciably from those at normal temperature. Two forms of the instrument are

described, one being direct reading and the other of the null type. Particulars are given of the calibration of the instrument in a horizontal wind channel, in a vertical hot-air channel, and when moved slowly downward in still air by means of a form of Attwood's machine. An illustration is given of the measurement of convected heat by means of the instrument. F.P.H.

Convection of heat in cases and liquids. I. Convection of heat and similitude. A. H. DAVIS. *Nat. Phys. Lab.*, **19,** 181(1926); reprinted with modifications from the *Philosophical Mag.*, Vol. 40, 1920.—(1) The hydrodynamic basis of convection of heat suggests study by means of molds. (2) We have the formulas:

$$\text{Natural convection} \qquad h=\left(\frac{k\theta}{l}\right)F\left(c^2g^2a\theta/k^2\right)$$

$$\text{Forced convection} \qquad h=\left(\frac{k\theta}{l}\right)F\left(lvc/k\right)$$

(3) Graphs drawn with $h/k\theta/l$ as ordinate and either $c^2g^2a\theta/k$ or (lvc/k) as abscissa should be independent of the size of the object; consequently to ascertain the heat-loss for any particular body it should be necessary only to perform the appropriate experiment with a model. (4) For natural convection Peclet's data have been analyzed with promising results. The formula would not be applicable to bodies where the fluid expansion caused was no longer negligible as a mere volume change. (5) For forced convection the formula, tested by data given by Hughes, is very promising. The cooling fluid is not heated so much as in natural convection, and can still be regarded as incompressible for smaller bodies at higher temperatures. The formula is good, even for thin wires, and it is satisfactory to trace in it the hydrodynamic variable determining turbulence. (6) Evidence available in published data indicates that, for heat-loss from a body, an excellent first approximation can be obtained from experiments with a model. The principle of similitude affords a convenient method of expressing experimental results. F.P.H.

Convection of heat in gases and liquids. II. Natural convective cooling of wires in gases. A. H. DAVIS. *Nat. Phys. Lab.*, **19,** 193(1926); reprinted from the *Philosophical Mag.*, Vol. 43, 1922; abstract reprinted from *Sci. Abs.*, (Physics Section A) Vol. 25).—In continuation of previous work D. investigates the apparent discrepancy between published data for the natural or free convective cooling of thin wires and the hydrodynamical theory. The hydrodynamical relation may be expressed in the form $H/k=F(\theta d^3/\nu^2)$, where H represents the heat-loss per unit length per degree temperature excess of the cylinder, k, the thermal conductivity of the cooling fluid, θ, the temperature excess of the cylinder of the diameter, d and ν, the ratio of the thermal conductivity of the fluid to its thermal capacity per unit volume. Using values of k and ν appropriate to individual experiments, such values being calculated in the cases of thin wires of the mean temperature of the wire and its surroundings, it is shown that the above relation accurately represents the results contained in the published work of Langmuir for the free convection losses from fine platinum wires at temperature excesses from 200°C to 1600°C of Ayrton and Kilgour for fine wires, Petavel for the heat-loss from steam pipes up to 1 foot in diameter and from a fine wire in various gases, and of Kennelly. The hydrodynamical formula developed is therefore seen to be in agreement with the published data for fine wires, provided allowance be made for the temperature changes of the properties of the cooling fluid owing to the high temperatures at which such wires have been usually employed. F.P.H.

Convection of heat in gases and liquids. III. Forced convective cooling of wires in gases. A. H. DAVIS. *Nat. Phys. Lab.*, **19,** 203(1926); reprinted with modified

title, from the *Philosophical Mag.*, Vol. 41, 1921.—In an earlier paper (*Nat. Phy. Lab. Collected Researches*, **19**, paper 11, or *Phil. Mag.*, **40**, 692(1920)) it was shown that Boussinesq's formula, as derived from considerations of similitude by Rayleigh, is well borne out by some published results for the cooling of cylinders in a stream of air. For gases the formula may be written $H/K = F(VL/\nu)$, where H is the rate of heat-loss per degree temperature excess by unit length of an infinite cylinder of diameter, L, when immersed in a stream of gas of which k, v, and ν are respectively the thermal conductivity, the velocity, and the kinematical viscosity. Here (VL/ν) is the familiar hydrodynamical variable determining fluid resistance and turbulence. The present paper extends the study. In the case of very hot wires some allowance is made for the changed physical properties of the heated gas near the wire. It is then found that a single curve will represent results obtained by various observers, a wide range of air velocity, air pressure, wire diameter, and temperature excesses being covered. The formula is further compared with the dynamic relation $(R/\rho V^2L^2) = f(VL/\nu)$, where R is the fluid resistance per diameter length of the wire, and ρ the density of the fluid. The relation between the thermal and mechanical effects experienced by a wire immersed in a steam was not found to conform generally with the simple formula $H \propto R/V$ advanced by Osborne Reynolds for fluid flow through a pipe. There appears, however, to be a tendency towards the Reynolds relation as the size of the cylinder is increased. F.P.H.

Convection of heat in gases and liquids. IV. Natural convective cooling in viscous gases and liquids. A. H. Davis. *Nat. Phys. Lab.*, **19**, 213(1926); reprinted from the *Philosophical Mag.*, **44**, 1922.—It has been shown in a previous paper that the loss of heat by natural convection from similar bodies immersed in viscous fluid can be expressed by the relation $hL/k\theta = F(c^2gL^3a\theta/k^2)f(c\nu/k)$ where the symbols have the meaning given below. For gases the relation is simplified since $(c\nu/k)$ is constant, and good agreement has been found between experimental results and the simplified formula. The case of viscous liquids is now considered. A theoretical investigation is given which shows that in certain cases the general formula takes the special form $hL/k\theta = F(L^3\theta gac/k\nu)$. To test the accuracy with which this equation may be substituted for the more general one, and to determine the form of the function involving $c\nu/k$, experiments were conducted on the cooling of electrically heated wires immersed horizontally in various liquids. The liquids tested were toluene, carbon tetrachloride, aniline, olive oil, and glycerine. If d represents the diameter of the wire and H, the heat-loss per unit length of wire per degree temperature excess, the relation between H/k and $(c^2gd^3a\theta/k^2)$ is shown to be given by a family of curves having $c\nu/k$ as parameter. The results obtained can be expressed by the relation $H/k \propto (c^2gd^3a\theta/k^2)^x(c\nu/k)^{-y}$ where x varies from $\frac{1}{10}$ to $\frac{1}{6}$ and y varies from $\frac{1}{10}$ to $\frac{1}{6}$. If $x = y$ we obtain $H/k \propto (d^3\theta gac/k\nu)^x$; this equation, which is of the special form indicated above, is shown to be satisfactory by plotting H/k against $(d^3\theta gac/k\nu)$ when one line covers the results for all the fluids considered. The variation of viscosity with temperature is allowed for but temperature variations of other properties are neglected. Apparently, judging from cases so far studied, the cooling power of a fluid may be represented by $h \propto k(ac/k\nu)^n$, where n varies from 0 to $\frac{1}{4}$, and thus the cooling power of a fluid is mainly determined by its thermal conductivity. F.P.H.

Convection of heat in gases and liquids. V. Some thermal conductivity data for liquids. A. H. Davis. *Nat Phys. Lab.*, **19**, 233(1926); reprinted from the *Philosophical Mag.*, Vol. 47, 1924.—Determinations have been made of the manner in which the thermal conductivity of a number of liquids varies with temperature. The work arose from the fact that the liquids, toluene, carbon tetrachloride, olive oil, and aniline, had previously been used in experiments on convective cooling in liquids, and the rate of convective cooling had been found to increase faster than the temperature. In analyzing results it had been taken for granted that there was no increase of thermal

conductivity with temperature which could contribute appreciably to the effect, but another author deduced that the thermal conductivity of the liquids increased by as much as about 1% per degree temperature rise. The present determinations, made by means of the Goldschmidt method over a temperature range of about 20 to 75°C, confirmed that the thermal conductivity does not increase with temperature, and the slight variation found was actually a decrease. F.P.H.

Convection of heat in gases and liquids. VI. Theory of forced convective cooling in viscous gases and liquids. A. H. DAVIS. *Nat. Phys. Lab.*, **19**, 239(1926); reprinted from the *Philosophical Mag.*, Vol. 44, 1922, as modified and extended by the subsequent note in Vol. 49, 1925.—A theoretical investigation is given of forced convection from a hot body immersed in an infinite stream of viscous fluid. The treatment follows that given by Boussinesq for inviscid fluids. It is assumed that the steam velocity (v_∞ at a distance from the body) is great enough for the effects of natural convection to be neglected. For a family of similar bodies, similarly oriented, having a temperature excess θ and linear dimensions given by L, it is shown that the mean heat loss h per unit area is given by $hL/k\theta = F(v_\infty Lc/k)$ provided $k/c\nu$ is either equal to unity or is very small. Here k, c, and ν refer respectively to the thermal conductivity, the specific heat per unit volume, and the kinematical viscosity of the fluid. The formula should tend to be satisfactory for gases on the one hand and for very viscous liquids on the other, and this has been confirmed by published results for gases and by experiments with viscous liquids, as described in a later paper. If the value $k/c\nu$ is not restricted we have $hL/k\theta = F\{(v_\infty Lc/k); (k/c\nu)\}$. F.P.H.

Convection of heat in gases and liquids. VII. Experimental study of forced convective cooling in viscous liquids. A. H. DAVIS. *Nat. Phys. Lab.*, **19**, 245(1926); reprinted with modified title from the *Philosophical Mag.*, Vol. 47, 1924.—Study has been made of the cooling of wires immersed in streams of various liquids. Theoretical considerations point to a formula of the type $H/k = F(vdc/k; k/c\nu)$, where H = heat loss per unit time per unit length of the wire per degree temperature elevation, k = thermal conductivity of the fluid, c = specific heat of the fluid per unit volume, ν = kinematical viscosity of the fluid, v = velocity of the fluid stream, d = diameter of the wire. Since $(k/c\nu)$ is practically constant for gases, the present experiments with liquids were undertaken to reveal its importance. The apparatus consisted of a motor-driven whirling arm which carried the test-wire and forced it continually through the liquid contained in an annular circular trough. Observation was made of the temperature of the wire and the electric energy necessary to maintain temperature difference between the wire and the general body of the fluid. Wires of three sizes were used, and various liquids whose physical constants were measured. The results showed that the above formula is fairly satisfactory, except that a factor must be included to cover certain small residual effects dependent upon d (and possibly θ) and due to some cause, possibly free convection, not fully investigated. It was found that the function, F, could not be represented by the product of two independent terms in vdc/k and $k/c\nu$ respectively, but that each influences to some extent the effect of the other. The following form was found to be satisfactory: $H/k = R \cdot f(k/c\nu) \cdot F\{(vdc/k) \times (k/c\nu)^{\frac{1}{2}}\}$, where R represents the residual factors referred to. Curves are given showing the forms of the two functions. If they are represented by power terms thus, $f(x) = x^{-m}$ and $F(x) = x^n$, m and n vary with circumstances but lie within the limits given by $0 < m < 0.19$ and $0.48 > n > 0.38$. For very viscous liquids m tends to 0.19 and n to 0.38, so that H/k then varies as $R(vdc/k)^{0.38}$. Concise tables present the experimental results. An estimate was made of the velocity of the natural convection current set up by the heated wire. F.P.H.

Determination of CO_2 in carbonates. ANON. *Analyst*, **51**, 622–24(1926).—From 0.15 to 0.5g. of calcium carbonate or other carbonate is weighed into a small beaker or

test tube. The material is covered with distilled water and transferred to a filtration flask containing 50 cc of $N/10$ barium oxide solution. A separatory funnel containing $3\,N$ HCl is placed over the flask and the whole apparatus made tight after which the air within the flask is exhausted until a pressure of 20m Hg is arrived at. The exhaust pump is then shut off and the hydrochloric acid fed slowly into the flask. The CO_2 gas on evolution is absorbed by the barium oxide solution and after evolution has ceased the contents are set aside for 12 to 24 hours. The unconverted barium oxide is titrated with $N/10$ oxalic acid from which the amount of CO_2 absorbed can be calculated. Results within 0.5% of theoretical are said to be possible by this method. F.P.H.

Soils in 1926. H. J. PAGE. *Ann. Rept. Soc. Chem. Ind.*, **11,** 452, 468–79 (1926).—Progress is reported under the headings: Physical properties, colloidal matter, ionic exchange, absorption, and soil reaction, electrokinetic phenomena, flocculation, drainage, methods of examination and analysis. The International Soc. of Soil Science holds its congress at Washington next June. Three Commissions: I. Soil Physics; II. Soil Chemistry; III. Soil Biochemistry and Biology, have held meetings during the past year in preparation for the congress. H.H.S.

Diffusion in solid solution. J. S. DUNN. *Jour. Soc. Chem. Ind.*, **46 T**, 109 (1927).—The diffusion equation

$$C_x = C_o\left\{1 - \frac{2}{\sqrt{\pi}}\int_0^{\frac{x}{2\sqrt{Dt}}} e^{-u^2}\,Du\right\}$$

conforms with the parabolic law $W^2 = Kt$ rather than with the logarithmic law $W = K \log t + A$. H.H.S.

Direct determination of distribution curves of particle size in suspensions. E. W. CROWTHER. *Jour. Soc. Chem. Ind.*, **46 T**, 105–107 (1927).—A paper from the Soil Physics Dept. of the Rothamsted Exptl. Station. An apparatus is described for obtaining continuous size-distribution curves of suspensions through measurements of the changes with time of the density at a given depth. A highly-sensitive differential liquid manometer connected between 2 points near the base of the sedimenting column is used to secure sufficient magnification for direct readings from which the size-distribution is calculated by Stokes' Law. (*Cf.* Lubirski and Kosman, *Ceram. Abs.*, **6** [4], 158 (1927)). H.H.S.

The imperfect crystallization of common things. WILLIAM BRAGG. *Engineering*, **123,** 128–30 (1927).—X-ray analysis of crystals is leading to an understanding of the internal structure of solids, and to a new branch of chemistry, the chemistry of solids. It enables us to connect the properties of solids with the arrangement of their particles. Crystallization, if only imperfect, is far more common than has been supposed. Crystalline agglomerates have been discovered even in cotton and rubber, sometimes devoid of orderly arrangement, sometimes oriented. Photographs accompany the article, and it is suggested that the tensile strength of any material is dependent on crystalline orientation and its changes under stress. H.H.S.

The polymorphism of silicon dioxide and the structure of tridymite. R. E. GIBBS. *Proc. Roy. Soc.* (London), **A113,** 351–68 (1926).—A structure is suggested for tridymite, on the assumption that a tetrahedron of O-atoms is built around a Si-atom. The assumption is justified by X-ray analysis. (*C. A.*)

Solid solution and chemical compounds. G. PHRAGMEN. *Tek. Tid.*, **56** (Kem. afd.), 81–85 (1926).—This paper is in large part a discussion of the designations "isomorph," "solid solution" and "chemical compounds" (molecular entities). The discussion is based on original Laue photographs of crystalline systems Fe–Si and Cu–Al. The former conforms to $Fe_{26}Si_{19}$. There is a difference in the cube edge between the Si-rich and Si-poor samples amounting to 5 times the average deviation. Stoichiomet-

ric proportions do not strictly apply to either system and the molar identity is questioned. The close approach to stoichiometry is explained by regular geometric atom distribution. X-ray photographs of both systems are given. (*C. A.*)

United States Government master specification for soda ash. Bur. Stand., *Circ.* No. 314, 5 pp. (1926). (*C. A.*)

A laboratory flow meter all in glass. H. L. PEATTIE AND F. B. BRADY. *Jour. Sci. Instr.*, **1**, 219 (1924).—The instrument shown had a perforated glass diaphragm of at most one-sixth the diameter of the surrounding tube, and a manometer tube, graduated either in linear marking or directly in volumes per unit time. The slope of the manometer tube was roughly one in 10 and its length as made by the authors 20–30 cm. A reservoir bulb, 4–5 cm diameter, was so placed that the zero level in the tube coincided with the widest part of the bulb, and another bulb served as a catch bulb. Manometer liquid was introduced through an opening normally kept closed. Levelling of the instrument was necessary to insure reproducible readings, and was performed by adjusting the position so that the menisci coincided with marks engraved on the tubes at the positions of the menisci when the tube was carefully levelled. The instrument was calibrated from the equation $v^2 = k(p - p')$ [where v was the rate of flow, $(p - p')$ the manometric head; and k, a constant for the apparatus] by comparison with a gas meter. Its special usefulness lay in measuring rates of flow of corrosive gases. For dry chlorine or hydrogen chloride it was charged with concentrated H_2SO_4, and for dry nitrous gases with a heavy paraffin. (*Jour. Soc. Glass Tech. Abs.*)

An apparatus for measuring the thermal expansion of glasses and wires. P. SELÉNYI AND E. PATAI. *Z. Instr.*, **46**, 246 (1926).—The apparatus, which was designed as a quick means of testing glasses for lamp bulb work, employed the expansion of an inner thin rod or wire, (to be tested) against an outer quartz cylinder, to measure the expansion of the rod. The difficulty of bringing fiduciary marks on the 2 expanding members into the field of the reading microscope was overcome. A piece of razor blade was fastened to the screw at the end of the inner quartz tube attached to the lower end of the thin rod under test. The water quartz tube supporting the top end, carried at its lower extremity a carriage, supporting a stout tube in which worked a plunger actuated by a nut, and prevented from rotating by a lock nut. The plunger carried on its upper face a mirror and the image of the razor blade was brought into juxtaposition with the blade itself when viewed through a reading microscope by suitable adjustment of the nut; a steam jacket round the outer tube provided the heating necessary and the movement of the edge of the blade relative to its image (being double the actual shift owing to reflection) was observed with an eyepiece micrometer. To prevent friction between the quartz tubes a light weight was hung from a wire stirrup attached to the inner rod. Measuring the glass rods with a millimeter scale and using an approximate length of 30 cm gave results accurate to about 1%. (*Jour. Soc. Glass Tech. Abs.*)

A new capillary electrometer. C. E. BENNET. *Jour. Opt. Soc. Amer.*, **11**, 411 (1925).—The inverted U-tube of capillary bore, was 0.012 cm radius. The limbs, about 10 cm long, dipped into very pure mercury cups connected by platinum wires to the terminals shown. The bend of the U-tube was filled with dilute sulphuric acid and a connection made by a tube with a reservoir vessel in communication with an aspirator. A cork served to hold the vacuum. The scale, illuminated from behind, was read with a telescope. With the size of bore chosen, the deflection for about 1 volt was about 15 mm. (*Jour. Soc. Glass Tech. Abs.*)

A general utility reading lens for burettes and thermometers. E. Q. ADAMS. *Jour. Opt. Soc. Amer.*, **12**, 375 (1926).—The device consisted of a lens of about 3.5 cm focal length mounted in a brass tube having a horizontal ocular slit 0.15 cm wide placed a distance in front of the lens equal to its focal length. This tube was arranged to slide in an outer tube carrying clamps which held the contrivance against burettes or ther-

mometer stems, so that the lens was roughly distant from the scale engraved thereon, a distance also equal to its focal length. The clips could be made to carry a background of alternate black and white stripes 0.5 mm wide to facilitate taking readings with colorless liquids. (*Jour. Soc. Glass Tech. Abs.*)

A new spiral gas washing bottle. L. H. MILLIGAN. *Jour. Opt. Soc. Amer.*, **12**, 518(1926).—The gas entered at the bottom of the massive spiral block which just fitted the cylindrical sleeve sliding loosely in the main outer cylinder. The inlet and exit tubes could be fused into a ground glass stopper, or pushed through a rubber one. The gas in its passage round spiral was in contact with the scrubbing liquid for a considerable time. Another good feature was the easy accessibility of all parts for cleaning. (*Jour. Soc. Glass Tech. Abs.*)

BOOKS

Progress of applied chemistry: Annual report, 1926. London: Society of Chemical Industry, 1927. Price 12*s* 6 *d*. The section on glass is by A. Cousen, and that on refractories, ceramics, and cement by A. T. Green. Other sections are: Plant and machinery; fuel; gas, and tar products; mineral oils; coloring matters and dyes; fibers, textiles, cellulose, and paper; bleaching, dyeing, printing, and finishing; acids, alkalis, salts, etc; iron and steel; nonferrous metals; electro-industries; oils, fats, and waxes; paints, pigments, varnishes, and resins; rubber; leather and glue; soils and fertilizers; sugars, starches, and gums; fermentation industries; foods; sanitation and water purification; fine chemicals, medical substances and essential oils; photography; explosives. H.H.S.

Gmelin's Handbuch: Wismut (Bismuth), 8th edn. Berlin: Verlag Chemie, G. m. b. H., 1927. Price 33 *m*. H.H.S.

Chemical Engineering Economics. C. TYLER. 271 pp., 66 illustrations. New York: McGraw-Hill Co., 1927. Price $4.25. T. is assistant editor of *Chem. and Met. Eng.* The first 2 chapters deal with the characteristics and statistics of the subject. Then follow chapters on development of new projects, principles of plant location, plant layout and design, cost accounting, unit operation costs, management, fuels and energy, operation and control. H.H.S.

PATENTS

Process of decreasing the rate of crystallization of borax from brine. A. W. GAUGER AND H. H. STORCH. U. S. 1,621,927, March 22, 1927. The process of decreasing the rate of crystallization of borax from brine containing sodium, potassium, chloride, carbonate, sulphate, metaborate, and tetraborate which comprises adding a resinous organic material to the brine and subjecting the brine to treatment to crystallize out other salts.

Production of a sodium-aluminium borosilicate glass. SIBOR, S. A., VERRERIES DE ROMONT. Eng. Pat. 245,131, Dec. 21, 1925. (*Brit. C. A.*)

General

Report of General Secretary, 1926-27. ROSS C. PURDY. *Bull. Amer. Ceram. Soc.*, **6** [4], 79–83 (1927).—The work being done by the SOCIETY, due to the coördinated coöperation of all members, is discussed. The membership record, financial status, work on various bibliographies already compiled and in the process of compilation, and correlation of technical interests of all ceramic organizations under an American Ceramic Research Council are other items taken up. E.J.V.

Conference on ceramic research. Led by A. F. GREAVES-WALKER. *Bull. Amer. Ceram. Soc.*, **6** [4], 84–96 (1927).—A full report of the discussion on ceramic research and the establishment of a Ceramic Research Council held in the general session at Detroit.

A vote taken showed the SOCIETY to be in favor of the Board of Trustees proceeding in an effort to organize the proposed American Ceramic Research Council. E.J.V.

Lots of pep at Pacific Coast meeting. ANON. *Amer. Glass Rev.*, **46** [26], 27 (1927). —A report of the sessions of the Pacific Coast Division of the National Glass Distributors Association on March 4th. E.J.V.

American Ceramic Society convention papers. ANON. *Glass Ind.*, **8** [4], 76–78 (1927).—Reviews of the following papers are given: "Design and Service of Tank Blocks," by Donald W. Ross; "Art Design of Glass Ware," by Frederick H. Rhead; "Large Clay Shapes for the Window Glass Industry," by Edwin P. Arthur; and "Durox Glass House Refractories", by T. S. Curtis. E.J.V.

The Kaiser Wilhelm Institute for Silicate Research and its aims for the present and future. W. EITEL. *Glastechn. Ber.*, **4** [4], 142–46 (1926).—A description of the Institute, its equipment and work being carried on at present and proposed investigations for the future is given. E.J.V.

Report February Society of Glass Technology meeting. ANON. *Nat. Glass Budget*, **42** [46], 24 (1927).—Abstracts of the following papers read at the February 26th meetings are given: "A Critical Survey of the Method in Use for the Analysis of the Simple Glasses," by W. H. Withey; "A Note on Methods Used in the Analysis of Glasses," by Violet Dimbleby; "The Analysis of Refractories," by W. J. Rees; and "Notes on the Analysis of Silicate Slags," by T. P. Colcough. E.J.V.

Pennsylvania the leader in ceramic production. J. B. SHAW. *Nat. Glass Budget*, **42** [46], 25 (1927); reprinted from *Pennsylvania Manufacturer's Journal*.—A survey of census statistics shows Pennsylvania to have about one-fifth of the capital investment and a production of about one-fourth of all the ceramic products of the United States. Needs of the industry are discussed. The Department of Ceramics at Penn State is discussed as to its establishment, equipment, related cources, etc. E.J.V.

The Society of Glass Technology. ANON. *Pottery Gaz.*, **52** [598], 664–66 (1927).— A full report of the discussion as to the prospects of holding a big glass convention in the near future. E.J.V.

The status of dry pressing. G. CAESAR. *Tonind. Ztg.*, **50,** 50th Anniv. No., 28 (1927).—Originally all clay products were molded from clay in the plastic condition, that is with 25 to 30% water. The dry-press process was first used in Germany in the 19th century by Villeroy and Boch in Mettlach and later by Sinzig Clay Products Co. for pressing mosaic tile. Some advantages of dry pressing are the production of ware with a true shape, high strength, low drying shrinkage, and a short time of drying. The presses are operated by hand, with a cam, and also hydraulically. This process is now used for brick, clinker, floor and wall tile, refractories, acid proof ware, and porcelain, especially electric porcelain. In America this process has been applied to a large variety of clays for common and face brick. In Germany, however, its use is limited to shales in brick making. The shale is ground, mixed with 10% water and is molded into brick. This water content is higher than that used for the regular dry press process which requires only 6% water so it is called a semidry-press process. In hydraulic presses a pressure of 200–300 atmospheres is applied to the ware by means of multiplying levers. In all dry-press processes the powdered material containing about 6% water is fed into the mold and first a low pressure is applied to permit the air to escape after which a much higher pressure is exerted on the ware. H.G.S.

Heat balance in industrial plants. C. A. KELSEY. *Blast Fur. Steel Plant*, **15** [4], 193–97 (1927).—A discussion of the utilization of steam with the resulting economies is given. Emphasis is placed on the part played by the turbine. F.P.H.

Watch your trade-mark. L. T. PARKER. *Brick Clay Rec.*, **70** [6], 473–74 (1927).— P. tells how manufacturers may avoid trade-mark litigation. A surname in a trade-mark may be prohibited as also a name which is misleading. F.P.H.

Glimpses into some European plants. E. J. CASSELMAN. *Ceram. Ind.*, **8** [4], 425–26 (1927).—A description of several glass and refractory plants visited by C. F.P.H.

Several interesting papers read before terra cotta men. ANON. *Ceram. Ind.*, **8** [4], 464–68 (1927).—Abstracts of papers presented before the Terra Cotta Division of the AMERICAN CERAMIC SOCIETY at the February 1927 Meeting. F.P.H.

Review of Common Brick Manufacturers Association Convention. ANON. *The Clay-Worker*, **87** [4], 294–99 (1927).—Report of the 1927 convention of the C. B. M. A. The following papers are abstracted (1) "Brick Engineering" by L. B. Lent, (2) "How Strong Is a Brick Wall" by J. W. McBurney. F.P.H.

Cost and accounting as applied to the clay industries. RICHARD C. TURNER. *Clay-Worker*, **87** [4], 301–302 (1927).—The second of a series of articles on this subject. In this article factors other than manufacturing that enter into the cost of clay products are considered. These factors are handiing charges, freight, allowances and rejections, selling or trading costs, and cost of administration. F.P.H.

American Ceramic Society Meeting. ANON. *Clay-Worker*, **87** [4], 312–14 (1927).—Report of the 29th Annual Meeting of the AMERICAN CERAMIC SOCIETY. Papers of interest to the heavy clay products industries are abstracted. F.P.H.

Society of Chemical Industry, Edinburgh Meeting, 1927. ANON. *Chem. and Ind.*, **46,** 265 (1927).—The program of the meeting to be held July 4–8 in Edinburgh, Scotland. The office of the society during the meeting will be in the North British Station Hotel, Princess Street, Edinburgh. H.H.S.

Scientific and industrial research: Report of the Committee of the Privy Council for 1925–1926. ANON. *Chem. and Ind.*, **46,** 274–75 (1927).—Further grants have been made to refractories, cast-iron, silk, rubber and tyre, leather and other associations, but not to shale oil and sugar. New research associations include preserved food, and paint, color and varnish. The Advisory Council considers that far too many men are specializing in chemistry, whereas there is a lack of those who combine chemistry with other subjects such as agriculture, biochemistry, and so on. It is pointed out that research must be regarded not as a cure for, but as a prevention of, bankruptcy. The estimated net expenditure of the department on research for the present year is £442,877; for last year it was £380,263 and for the previous year £328,281. The report may be obtained from H. M. Stationery Office for 3 shillings. H.H.S.

Progress in plant and machinery in 1926. S. G. M. URE. *Ann. Rept. Soc. Chem. Ind.*, **11,** 5–21 (1926).—After referring to the protracted coal struggle in England and to the development of combines all over Europe, U. considers in due order: centrifugal separators, filtration, electric precipitation, evaporation, crystallization, drying apparatus, furnaces and heat interchangers, crushing and grinding machinery, catalysts, absorption, distillation, and refrigeration. An interesting engineering development has been the Avery Co's. construction of a 1250-ton testing machine, which can take specimens 50 ft. long and 36 sq. in. cross-section. H.H.S.

PATENT

Treatment of earthy minerals. WILLIAM FELDENHEIMER. U. S. 1,622,099, March 29, 1927. In the process for improving the color of earthy minerals, the step comprising bringing an aqueous suspension of the subdivided mineral into contact with a salt of sulphurous acid containing a salt of a metal which reduces sulphurous acid and does not form colored oxidized salts.

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Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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Vol. 6 June, 1927 No. 6

EDITORIALS

RELATION OF COMPOSITION AND HEAT TREATMENT TO INDUSTRIAL PROPERTIES OF CERAMIC PRODUCTS

A Plea for a Correlated Program of Fundamental Investigations

Definition of Ceramics

Ceramics is that science which deals with silicate mixtures and their fabrication into or onto utility wares. Clay, glass, and glass enamels are ceramic materials, and the wares made from them are ceramic products. The industries making ceramic products are classed as the silicate industries.

The art of selecting, compounding, fabricating, decorating, and rendering permanent in form and appearance by firing is ceramic art and technology. The designing and the controlling of means for making silicate wares is ceramic engineering.

Though different in outward appearances and possessed of distinctive product characteristics, all ceramic wares are fundamentally the same in the heat reactions which their constituent parts undergo in firing; the same general laws of silicate reactions hold for all ceramic wares.

Ceramic Wares are Made to Specifications

Each ceramic ware is made for a specific purpose. Brick for roads, walks, sewers, buildings, and for high temperature furnaces must, to some degree, meet specifications dictated by conditions of use. These specifications naturally cover size, form, and quality. Every

ceramic product must measure up to the dictates of the conditions under which it is to serve. Table china must withstand handling and machine washing, and at the same time be pleasing in appearance and appropriate in shape. Electrical insulators must under all weather conditions withstand electrical and mechanical strains, each varied condition of use requiring specific shape and size and composition of porcelain. Specifications of shape, size, composition, and finish of ceramic wares are being drawn closer and closer.

The Constitution and Physical Condition of Raw Materials

Ceramic Wares are Made with Natural Materials

Ceramic wares must be made to specification from the minerals found in nature. Quantity production and practical costs preclude use of hand-picked samples and chemically pure and physically altered materials.

Ceramic Science is Exact in Fundamentals

The science of ceramic ware production, though founded on the fundamental science facts, becomes involved by the chemical, mineral, and physical nature of the raw materials, and by the economic factors involved in the gathering, preparing, and processing of the raw materials. Ceramic science is exact in fundamentals but empirical in its applications, and this is true even in glassmaking in which fewer and purer raw materials are used and in which the fusion is carried practically to completion. This empiricism results from a chemical and physical complex in which it is beyond human possibility to correlate even the recognizable factors. There are several factors that are not recognizable.

Properties of Clay Wares Depend on Fused and Unfused Portions

In clay wares the fusion of minerals is not carried to completion. Enough material must remain unfused to give rigidity to the ware during the process of partial fusion. In case of bricks it is impractical to fire them in kilns otherwise than in stacks. The bricks next to the kiln floor thus must carry the load of the superimposed bricks. Should the unfused portions of the clay be insufficient in amount or should it not be sintered sufficiently and be bonded by the fused or glassy portions, the brick at the bottom of the stack would be deformed by the superimposed load. In case of dinner plates the overhung rim must not settle down under its own weight. In clay wares there must be a sufficient amount of glass formed by fusion to give the ware its required strength, hardness, and vitrification, and there must be a sufficient amount of unfused material to give the ware rigidity and load carrying capacity while the glass portion is molten and to give to the completed ware its required physical re-

sisting properties. In brief, the properties of ceramic wares are influenced by the glass and by the undissolved portions of the partially fused or vitrified mass.

Ware Properties are Related to Mineral Constitution

The properties of the finished clay wares are related more to the physical properties and mineral constitution of the clays and minerals used than to their ultimate chemical composition.

Chemical analysis of the clay mix will not reveal its adaptability to the process used in forming the ware, and adaptability to processing has an important influence on the quality of the ware produced.

Chemical analysis will not disclose the mineral composition of the clay nor the particle size of the minerals. Both the kind of mineral and the particle size of the mineral influence the structure produced in processing, and also the rate at which the vitrifying glass is formed.

The rate and extent of mutual solution of two minerals with a given heat treatment is directly proportional to the amount of their surface contact; the smaller the particles, the greater the rate and extent of mutual solution. The finer the mineral particles, the more fusible will be the clay, modified of course by the fusibility of the minerals themselves.

Composition of Clays

Clays are comprised principally of hydrated alumina silicates, quartz, feldspar, and mica admixed with iron compounds, the hydrate of alumina, the carbonates of calcium and magnesia, oxides of titanium, etc. Many of the secondary clays contain phosphates, sulphides, etc. Whatever nature chanced by weather or by force to disintegrate to a powder and to sort, deposit, and render plastic is a clay.

Metamorphosed on such a large scale and transported by air and water there naturally are contaminations and infiltrations. Should this fine clay detritus be infiltered with calcium carbonate in sufficient amounts, the deposit will become a marl; if infiltered with sufficient colloidal alumina and then indurated by heat and pressure sufficiently to dewater the colloidal alumina, the clay will be a flint clay. If the infiltered alumina under the influence of organic acids should form spheroids the clay would have gibbsite, bauxite, or diaspor as an accessory mineral. Thus it is that we have our varied clays and shales, each with a chance mineral constitution and a chance physical condition.

Clays having the same chemical composition may be, and generally are, so different in mineral constitution and in physical characteristics as to be very different in adaptability to a given process of fabrication and quite different in character of product formed. The availability of minerals for solution is a factor.

Then too, there are the adsorbed salts. These salts, usually alkaline and alkaline earth, have a profound influence on that peculiarity of clays known as plasticity.

Adsorbed salts also have a profound influence on the fusing behavior of clays. Being spread over the surfaces of the grains in a colloidal coating these adsorbed salts cause a cementing of the grains under the influence of relatively low temperature heat treatments. This is known as sintering. Naturally these salts induce fusion of the minerals in a way and to an extent unlike that which these oxides would if they were a constituent part of the feldspars and micas.

Factor Determining Suitability of Clays for Specific Wares

Clays suitable for paving brick or for sewer pipe may have rather wide range in chemical composition. They must be comprised of mineral grains sufficiently small to be of colloidal dimension, these colloidal particles cemented in bundles which only partially slake in water so that the clay will form nicely in the machine die. These clays for sewer pipe and for paving brick must also be of a mineral constitution that will vitrify gradually as the kiln heat treatment progresses until the ware is practically impervious to water.

We can tell how a clay should perform in the machines and in the kilns, but no one has yet learned how by chemical or by microscopic means they can determine whether an unknown clay will so perform in the machines and in the kilns as to make it suitable for sewer pipes or paving brick.

Relatively pure mineral mixtures have been compounded that would form and fire suitably for pipe and for paving brick but, obviously, such compounded mixtures are too costly. Economically we cannot use any other than natural clay mineral mixtures for the production of sewer pipe and paving brick.

The only known way of determining the suitability of a clay for manufacturing into a given product is by putting the clay through the process and making tests on the product thus produced. This applies also to the white ball and china clays used in porcelain and to the relatively pure clays used in refractories.

The industrial availability of a clay is more dependent on its rate of vitrification and of its ultimate fusibility than on any other property. A clay suitable for making vitreous stoneware at ordinary kiln temperatures may be equally as refractory as the clays used in high grade fire brick.

Heat History Has Marked Effect on Ware Property

Long Heat Treatment Beneficial to Clay Wares

In the melting of glass and in the vitrifying of clay wares the heat history has a marked effect on the product. To attain the

maximum resistance to impact, the minimum expansion due to temperature changes and the minimum deformation in the kilns, porcelains and china should be given a long soaking heat treatment at a temperature just below that required to vitrify these wares. Vitrified clay wares should be given a long soaking heat to develop their maximum strength.

A pyrometric cone, No. 10, made of feldspar, calcium carbonate, clay, and flint will acquire what appears to be greater refractoriness if held long at a temperature just short of that required to cause it to bend over. The cone apparently is set; it will not fuse down until submitted to temperatures much higher than is normally required for that cone.

This phenomena of greater resistance to deformation, and the development of greater strength in vitrified porcelains by long holding at lower temperatures than are normally used in firing these porcelains, has not as yet been satisfactorily explained. A study of the equilibrium charts shows to what mineral compositions the clay-feldspar-flint-whiting mixtures will alter. We know that a considerable amount of mullite will be formed. We know also that the glass portion of vitrified porcelain is relatively very viscous at the vitrifying temperatures and will dissolve the more refractory components very slowly. The glass which would cause deformation of porcelains with high temperatures and shorter time will be more viscous and more refractory with lower temperatures, and the longer time probably allows the formation of more of the very refractory mullite and of immiscible solutions of cristobalite, mullite, and anorthite.

Long Heat Treatment Damaging to Glass

Long heat treatment at subnormal temperatures, which is beneficial to porcelains, is damaging to glass. Porcelains are not completely fused, the solution reactions being far from completed. Glasses, on the other hand, are fused completely, the components being entirely in mutual solution.

If the batch has been completely molten for an unusually long period, the resultant glass will have less strength and be more brittle.

The opposite effects in porcelains and glasses of holding at melting temperatures for a long period is noticeable also in such ceramic wares as grinding wheels, some of which are bonded with porcelain and some with glass. The heat treatment required to develop the maximum strength in clay wares is dependent upon the amount and the character of the glass which is formed and the alterations and solubility characteristics which affect the character of the unfused portions.

The reason for hotel china, paving brick, floor tile, porcelain bonded silicon carbide wheels, and fire brick being made stronger by long soaking at subnormal temperatures cannot be found by chemical analysis.

The longer heating at subnormal temperatures does not alter the relative proportion of the oxides present. Explanation for this strength phenomena is to be found in the different mineral formations and alterations resulting from fusion. This is a problem for the petrographer rather than for the chemist.

Devitrification, Crystallization, and Solid Solutions

One other citation of dependency of ware quality on mineral constitution rather than on chemical composition, is found in devitrification.

Devitrification of glass is the crystallizing out of solution of the mineral components of the glass. Glass is a perfect, but unstable mutual solution of silicates. If a glass devitrifies it is decreased in strength and will not withstand sudden temperature changes.

On the other hand if the character of the glass is such as will facilitate the crystallization of a constituent such as mullite, which is immiscible in the glass solution, the glass product at normal temperatures will be stronger. This is shown in spark plugs and other porcelain products, the heat treatment of which has permitted the development of mullite. It is shown also in fused mixtures of phosphates and silicates. China ware containing a small percentage of bone ash has greater strength and is more resistant to heat shock than if composed alone of clay, feldspar, and flint. Glasses composed of borates, silicates, and phosphates are the strongest. They appear to be miscible solutions with the tendency of one of the solutions separating out without causing the other solutions to devitrify.

Equilibrium Studies of Fusions Important

When we learn how to study the equilibrium of five and more component systems we possibly will find the fundamental relations of the constitution of clays, enamels, and other complex ceramic mixtures to the quality of the fabricated product. Very little progress has been made in such studies. The work done at the Geophysical Laboratories in Washington with simple mixtures of pure materials has revealed the only way known for finding the physicochemical relations between the raw material constitution and the quality of the completed silicate wares.

In the foregoing statements there is no depreciation of the importance of chemical and physical studies of ceramic materials and products. A knowledge of chemical and physical relations and reactions is absolutely essential to an understanding of the making of ceramic wares having specified properties. There is, however, a woeful lack of intelligent use of such knowledge due entirely to the lack of information of funda-

mental facts regarding the raw materials and their inter-reactions in fusion.

Plea for Fundamental Ceramic Research

Much progress in ceramics has been made by empirical application of such science information as has been made available. With each revelation of a fundamental fact, such as mineral equilibriums in fusions, there has been a decided advance in knowledge and concepts, and in manufacturing applications with the result that ceramic wares have been made to product specifications with greater certainty and economies. The need and the industrial value of fundamental facts concerning silicate materials and silicate fusions have been demonstrated.

This is a plea for a larger employment of the scientific research facilities and of the research capabilities of the staffs of our universities.

On the part of the industries and the universities there is a need of a rational research program of searching the fundamentals if progress in quality production of ceramic wares is to keep pace with the increasing exactitude in product specifications. The economics in production and in use of ceramic wares requires more knowledge of the ceramic fundamental science factors involved in silicate compounding and fusing, and the economics in the securing of this knowledge requires a closer working relation between the universities and the industries.

The American Ceramic Research Institute and Council has been proposed as an agency for making possible this needed closer working relation between the already financed and operating research laboratories which are seeking practical research problems and the ceramic industries which are badly in need of fundamental information. The Council would correlate known facts and disclose the unknown, and the Institute would finance the investigations and provide for training of men in the science of fact finding.

(Excerpt from *Through the Meshes*, May, 1927, publication of the W. S. Tyler Co., Cleveland, O.)

New industries today are being hatched in laboratories of applied science.

Research is becoming the most important word in the dictionary of business.

Even *Barron's*, the financial weekly, suggests that it is no longer fashionable to ascribe the success of a company solely to "the Napoleon of finance who directs its destinies." Success today is achieved by the efforts of a number of different groups of men of widely dissimilar training and education. H. G. Wells devotes many pages to this thought in "The World of William Clissold."

The attention that is given to research is strikingly illustrated in the budget of E. I. duPont de Nemours & Co., which carries an item of $2,500,000 for laboratory study. This is equal to $1 a share on the company's outstanding common stock, and as *Barron's* points out, is the premium this progressive company pays to insure its industrial leadership.

In discussing the duPont stock as an investment, *Barron's* makes this significant comment: "Perhaps the most important factor of all in considering the future of duPont is the chemical-research organization. Modern chemistry is rejuvenating long-established industries and creating new ones overnight. The company whose management possesses the foresight to spend millions for chemical research will be sure not merely to maintain its position in American industry, but to grow even more rapidly in strength and prosperity than the country as a whole.

MISEMPLOYMENT OF FUNDAMENTAL SCIENCE CONCEPTS

Service requirements of ceramic ware are being measured and expressed in terms of stress and life endurance. Testing methods have been refined and attempts made at writing specifications in terms of test data, but all without much success. Most of the tests devised measure resultant effects and not the fundamental causes. It is idle to measure expansion with expectation that the expansion data will reveal ability of ceramic ware to withstand service stresses, for expansion of ceramic ware is itself a composite effect and not a fundamental cause.

Too often effects are mistaken for causes. Two effects are altogether too frequently related in analysis of data as a cause and an effect. This error has been costly in wasted dollars and in retarded industrial progress.

In simple glasses the oxides have additive effect on the physical properties but there is evidence that such simple relations do not hold in glazes, in enamels, and in the glass bonds of vitrified clay ware. In fact, the values determined on simple glasses by different operators are quite varied. It may be that glass is not always what it appears to be. It may be that we have failed to distinguish true glass from the glass-like fusions, the glasslike fusions being those from which, when devitrified, the crystals will differ from the mother glass in composition. The oxides do not have a definite additive effect on the properties of the "glasslike" fusions such as glazes and enamels.

Fishscaling of enamels has been ascribed to differences in expansion of the enamel and iron, and a correction has been attempted on the theory that the oxides have additive influence on expansion of the enamel. This is an excellent working theory in the absence of other theories and known facts, ignoring, though it does, the basic fact that enamels are viscous glasses having a complex mineral constitition.

Fishscaling of enamels is akin to spalling of fire brick. They have quite similar causes. The cause and cure of fishscaling and of spalling will never be determined by measuring distantly related physical properties.

Crazing of glazes has been ascribed to difference in expansion of the glaze and body whereas there have been no data obtained that would warrant such assumption. The same glaze will "fit," "craze," or "spall" on bodies having radically different expansion coefficients.

No single measurement or series of measurements of the enamel, glaze, pottery body, or fire brick has lead to a formulation of the cause and cure of fishscaling, crazing, and spalling. Tests have failed to give data that are usable in specification writing, for these tests measure composite effects and not the fundamental causes.

Attempts to equate the several factors that seem to cause weakness or resistance have been of academic value but no control or corrective means have yet resulted from such studies. A fire brick will spall or will fail to carry load not because it has a certain elasticity, expansion coefficient, or tensile strength; spalling and load carrying capacity are related to the character of the glasslike and of the undissolved portions of the brick.

It would be wholly incorrect to say that there has been too much empirical investigation and it would be wrong to think that in the future there will be fewer empirical investigations in ceramics. Because of the complexity of the chemical and physical factors involved, empirical researches will always be necessary in making application of fundamental facts relating to ceramic materials. More intelligent empirical investigations are essential but this intelligence will be had only when there are more fundamental facts known regarding glasslike fusions.

It is a large financial waste not to have our university research facilities employed in finding the causative fundamentals in silicate fusions. The industries would benefit by facts made known and by men made proficient in searching for the fundamental causes and correctives for failures of ceramic wares under service stress.

We insist that adequate federal support and an equitable proportion of state taxes will not be devoted to ceramic fundamental researches until the ceramic manufacturers are organized to make their needs known. Ceramic manufacturers must not only organize for representations before the legislative appropriating bodies but must furnish a correlating and advisory research board that will lead in securing the most profitable procedures and problems. America needs a National Ceramic Research Council.

ACTIVITIES OF THE SOCIETY

NEW MEMBERS RECEIVED FROM APRIL 16 TO MAY 14

PERSONAL

J. H. D. Allen, President, Enfield Pottery and Tile Works, Enfield, Pa.
Harry Edwards, Dundas Cottages, Bonnybridge, Scotland.
Wallace M. Folger, Eastern Sales Representative, U. S. Refractories Corp., Philadelphia, Pa.
J. M. Harby, Plant Manager, Washington Brick, Lime and Sewer Pipe Co., Clayton, Wash.
Thomas B. Johnston, Managing Director, Messrs. Pountney & Co., Ltd., The Bristol Pottery, Fishponds, Bristol, England.
Lester Kirschbraun, Research Director, Flintkote Co., Rutherford, N. J.
Stuart L. Gunn, Factory Manager, McClary Mfg. Co., London, Ont.
Charles L. Norton, Jr., Research Assistant, Massachusetts Institute of Technology, Cambridge, Mass.
F. R. Porter, Edison Elec. Appliance Co., 5600 W. Taylor St., Chicago, Ill.
Charles Storch, Casino Theater, Republic, Wash.

STUDENT

H. Reford Aldridge, 89 E. Frambes Ave., Columbus, O.
Roy G. Ehman, 404 E. Daniel St., Champaign, Ill.
Kenneth D. Gould, 1349 Des Moines St., Des Moines, Iowa.
Christian W. Planje, 707 S. Third St., Champaign, Ill.
J. H. Weis, Box 500, State College, Pa.
E. T. Wheeler, 265 Wood Court, Wilmette, Ill.

Membership Worker's Record

	PERSONAL		STUDENT
E. deF. Curtis	1	C. M. Dodd	1
W. V. Knowles	1	D. A. Moulton	1
T. N. Kurtz	1	C. W. Parmelee	2
C. L. Norton	1	J. B. Shaw	1
Hewitt Wilson	1	Office	1
Office	5		
		Total	6
Total	10		

NORTH CAROLINA STATE COLLEGE STUDENT BRANCH

The Student Branch of the AMERICAN CERAMIC SOCIETY at North Carolina State College held its annual election on May 4 with the following results:

President	A. McKinley Greaves-Walker, '29
Vice President	W. L. Stafford, '28
Secretary-Treasurer	J. E. Boyd, '28
Representatives on Engineers Council	A. McK. Greaves-Walker, '29
	P. E. Trevathan, '28

In turning over the gavel to the new president, P. E. Trevathan, who has held the office during the past year, took occasion to compliment the organization on its fine show of interest and splendid record of attendance during the past nine months. He called attention to the fact that in spite of the greater size of some of the other technical societies the Branch had the best attendance record on the Campus.

After the installation a very interesting program was put on by the members who will graduate in June.

Three of the members were cited for honors in scholarship at the recent Scholarship Day exercises and one, Greaves-Walker, was awarded both the Tau Beta Pi and Phi Kappa Phi Scholarship medals for the year.

NOTES AND NEWS

OBITUARIES

Ira Harvey Woolson

Ira H. Woolson, of New York, mechanical engineer, died on May 8, 1927. Mr. Woolson was born at Lewiston, N. Y., Aug. 11, 1856. From 1891 to 1910 he was instructor and professor of mechanical engineering at Columbia University. For ten years he was official investigator of building materials in New York City. In 1903 he was the official delegate from New York City to the International Fire Prevention Congress in London. From 1910 until his death he was consulting engineer of the National Board of Fire Underwriters. He was also advisory engineer to the building materials division of the War Industries Board during 1918 and 1919. From 1921 until his death he was chairman of the Building Code Commision of the United States Department of Commerce. Mr. Woolson's death is regretted by all who knew him.

Lawrence M. Thomas

Lawrence M. Thomas, aged 73, pioneer ceramic manufacturer of East Liverpool, Ohio, died May 14 at Mt. Dora, Florida. He was president of the R. Thomas and Sons Company of East Liverpool and Lisbon, a corporation member of the SOCIETY.

RESEARCH FELLOWSHIPS IN COAL AND NONMETALLICS

The College of Mines of the University of Washington offers five fellowships for research in coal and nonmetallics in coöperative work with the United States Bureau of Mines. The fellowships are open to graduates of universities and technical colleges who are properly qualified to undertake research investigation. The value of each fellowship is $720 to the holder, for twelve months beginning July 1st. Fellowship holders pay tuition and laboratory fees, but are reimbursed for the amounts so expended; they register as graduate students and become candidates for the degree of Master of Science in the proper subject, unless an equivalent degree has previously been earned.

The purpose of these fellowships is to undertake the solution of various problems being studied by the United States Bureau of Mines that are of especial importance to the State of Washington, the Pacific Northwest, and Alaska. The investigations consist principally of laboratory work directed largely by the Bureau's technologists. The work will be performed in the building known as Mines Laboratory, which is now being doubled in size and fully equipped. For the year 1927-1928 the following subjects have been selected for investigation:

1. Coal.
   (*a*) Beneficiation: coal washing. Application of ore dressing principles to cleaning of coal.
   (*b*) Utilization: briquetting of low grade coals and other problems.

2. Nonmetallics.
   (*a*) Purification: washing of kaolins and ochres.
   (*b*) Problems in drying certain nonmetallics.
   (*c*) Efficiency studies in kiln-heating.

Each applicant should send a copy of his collegiate record from the Registrar of the college where he has graduated, or will be graduated in June. He should also send a photograph and a detailed statement of his professional experience, if any, and give the names and adresses of at least three persons who are familiar with his character, training and ability. Applications should be submitted by May 1, or as soon thereafter as possible in order to allow ample time for consideration, and should be addressed to Dean Milnor Roberts.

CALENDAR OF CONVENTIONS

Amer. Assn. for the Advancement of Science	Dec. 28–31, 1927	Nashville, Tenn.
Amer. Assn. Flint and Lime Glass Mfrs.	July 18, 1927	Atlantic City, N. J.
AMERICAN CERAMIC SOCIETY Annual Meeting	Feb. 5–11, 1928	Atlantic City, N. J.
American Chemical Society	Sept. 5–10, 1927	Detroit, Mich.
American Concrete Institute	Feb. 28, 29, Mar. 1, 1928	Philadelphia, Pa.
Amer. Electrochemical Soc.	Sept. 4–20, 1927	Trip through Northwest
American Engineering Council	January, 1928	Washington, D. C.
Amer. Foundrymen's Association	June 6–9, 1927	Chicago, Ill.
Amer. Gas Association	Oct. 10, 1927	Chicago, Ill.
Amer. Inst. Chem. Engrs.	June 1–4, 1927	Cleveland, Ohio
Amer. Inst. Mining and Met. Engrs.	February, 1928	New York City
Amer. Mining Congress	1st week Dec. 1927	Washington, D. C.
Amer. Soc. Mechanical Engrs.	Dec. 5–8, 1927	New York City
Amer. Soc. Steel Treating	Sept. 19–23, 1927	Detroit, Mich.
Amer. Soc. Testing Materials	June 20–24, 1927	French Lick, Ind.
Amer. Vitrified China Mfrs. Assn.	June, 1927	?
Amer. Zinc Institute	April 16–18, 1927	St. Louis, Mo.
Assn. Chem. Equipment Mfrs.	Sept., 1927	New York City
Assn. Iron and Steel Elec. Engrs.	June 13–18, 1927	Pittsburgh, Pa.
Exposition of Chem. Industries	Sept. 26–Oct. 1, 1927	New York City
Grinding Wheel Mfrs. Assn. of U. S. and Canada	June 16–17, 1927	Niagara Falls, Can.
Hollow Building Tile Assn.	February, 1928	Chicago, Ill.
Mfg. Chemists Assn.	June 2, 1927	New York City
Natl. Academy of Sciences	Oct. 18–20, 1927	Urbana, Ill.
Natl. Assn. of Mfrs.	Oct. 25–27, 1927	Chattanooga, Tenn.
Natl. Assn. of Mfrs. of Pressed and Blown Glassware	July 18, 1927	Atlantic City, N. J.
Natl. Exposition of Power and Mech. Engineering	Dec. 5–10, 1927	New York City
Natl. Safety Council	Sept. 26–30, 1927	Chicago, Ill.
New Jersey Clayworkers' Assn.	June 10, 1927	Asbury Park, N. J.
Optical Society of Amer.	Oct. 20–22, 1927	Schenectady, N. Y.
Stained Glass Assn. of Amer.	June 27, 1927	St. Louis, Mo.

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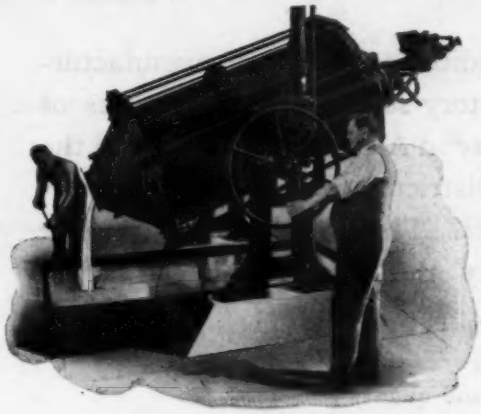

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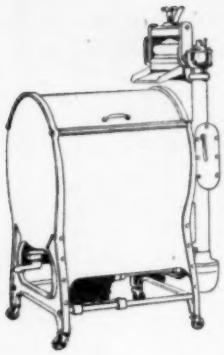

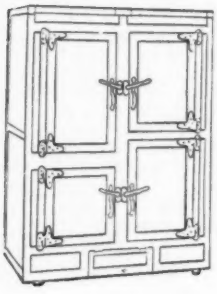

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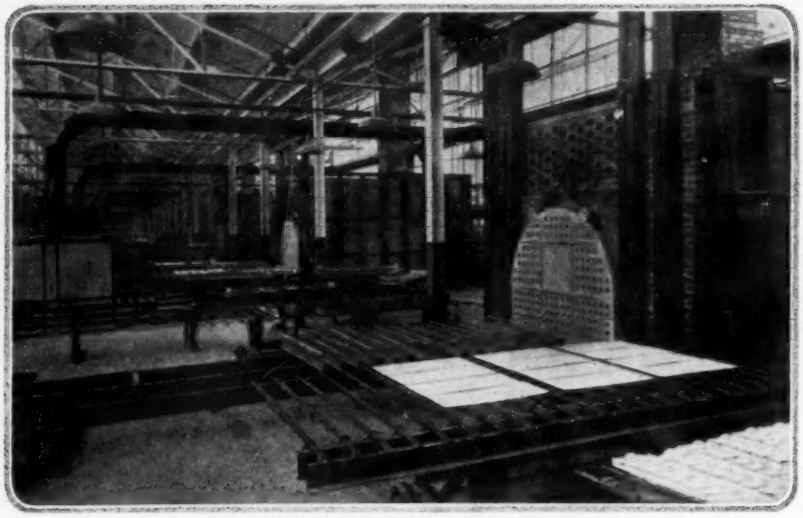

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Leeds & Northrup Co. have just issued an interesting bulletin on Electrical CO_2 Meters. Write them for Bulletin No. 781. You will find it worth your while.

The Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, Ill., have issued bulletin CO-34 dealing with flue gas analysis which should be in every ceramic engineer's office.

CERAMIC BREVITIES

Due to the large increase of business in Cincinnati and vicinity The Brown Instrument Company wishes to announce the opening on April 1, 1927 of a Cincinnati Branch, 718 First National Bank Building, Cincinnati, Ohio, J. R. Green, District Manager, Telephone, Main 6550. Users of Brown Pyrometers, Electric Flow Meters, CO_2 Meters, Recording Thermometers, Pressure Gauges and Tachometers, and the many concerns interested in temperature, flow, pressure, speed and combustion problems will appreciate this new Branch Office.

The Servel Corp., Manufacturers of Iceless Refrigerators, have placed contract with The Ferro Enamel Supply Company, Cleveland, Ohio, for two complete porcelain enameling furnaces to be erected in their plant at Evansville, Ind.

The Abendroth Bros. Co., one of the oldest stove companies in the country, is installing in its plant at Port Chester, New York, a complete department for porcelain enameling on sheet steel and cast iron.

The Detroit-Michigan Stove Works, Detroit, Mich., is building a large addition to its enameling department and is installing two complete new gas fired enameling furnaces. They are also installing several new Ferro loading and unloading forks, operated by air.

Major Wilfred Mavor has resigned as Eastern Representative of The Ferro Enamel Supply Co., to become manager of The Ferro Enameling Company of Canada, Limited. The new company is located at Ottawa, Ontario, Canada, and is a branch of the Ferro Enameling Company of Cleveland, Ohio. Officers of the new company are H. D. Cushman, President, and R. A. Weaver, Vice-president.

The Weaver Brothers Company was recently incorporated at Clinton, Mich., for the manufacture of metal cleaners, pickling baskets, and complete pickle room supplies for the general trade. J. C. Weaver is in charge of the plant. R. A. Weaver is President of the Company, and H. R. Ebright and H. L. Brooks are Vice-presidents.

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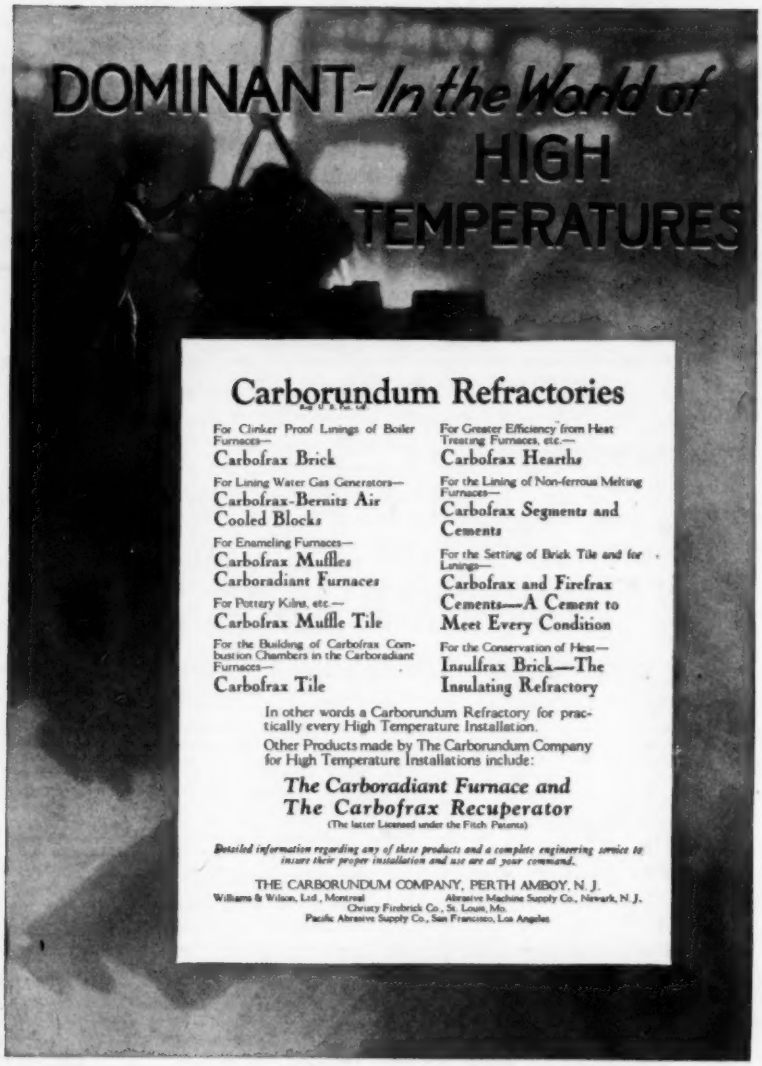
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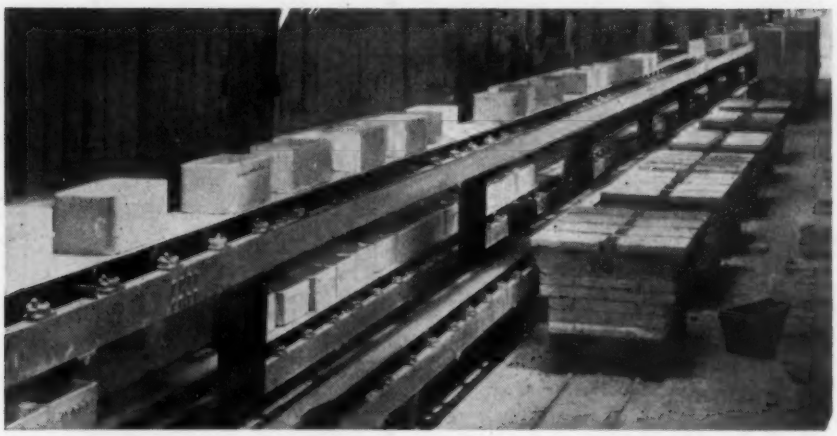

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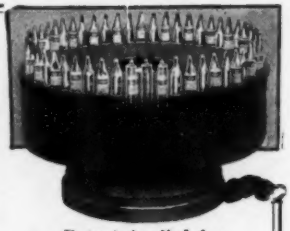

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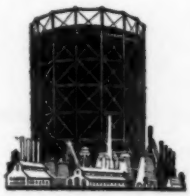

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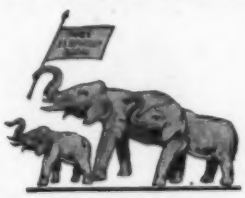

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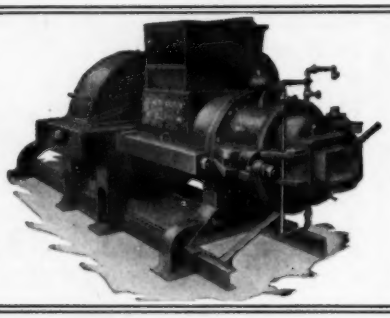

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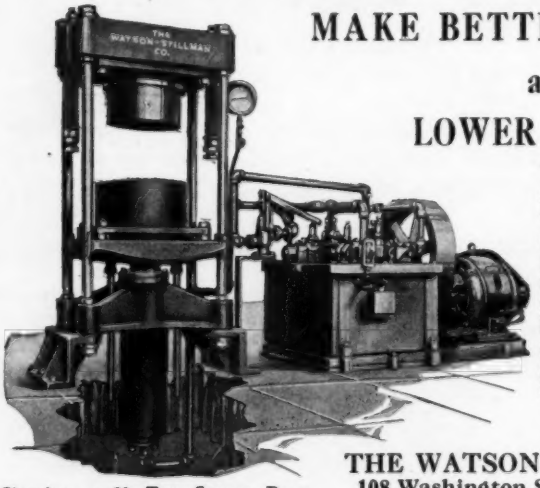

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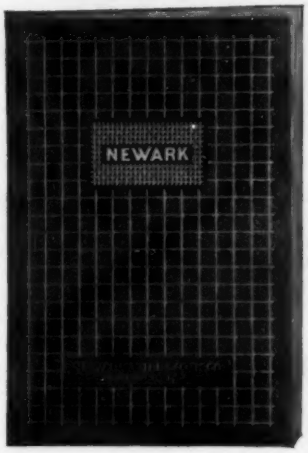

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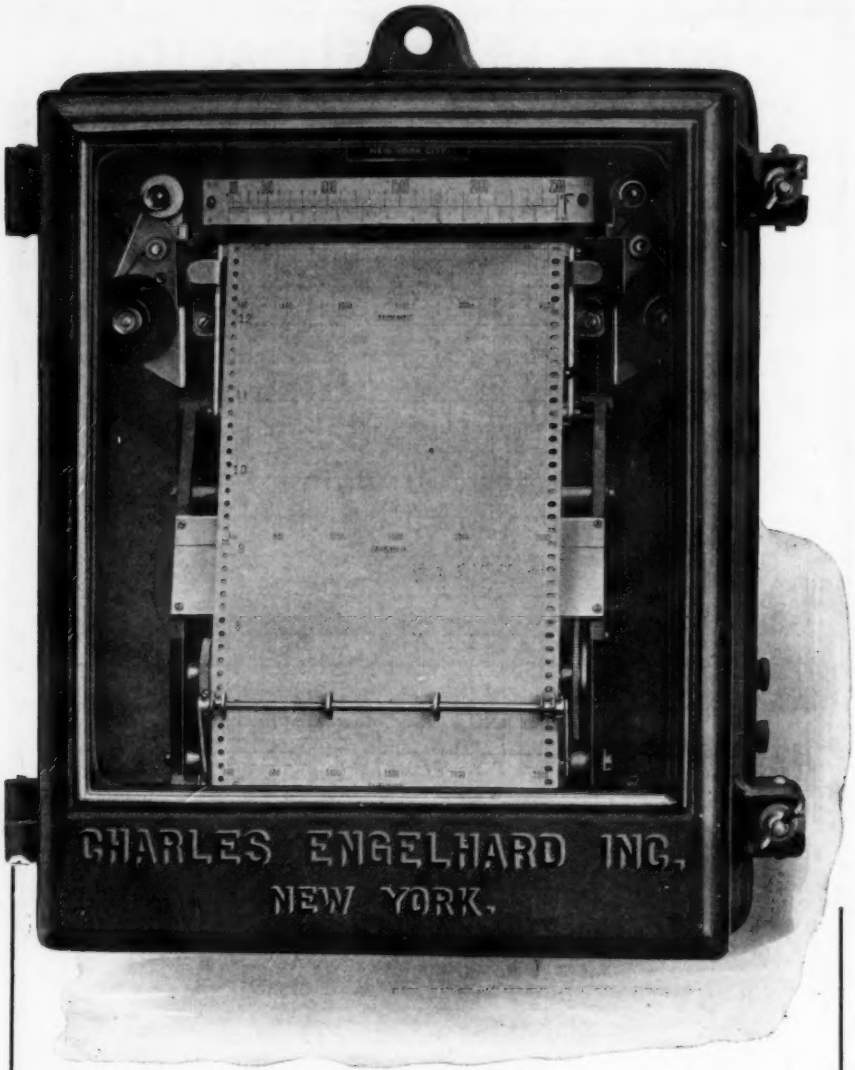

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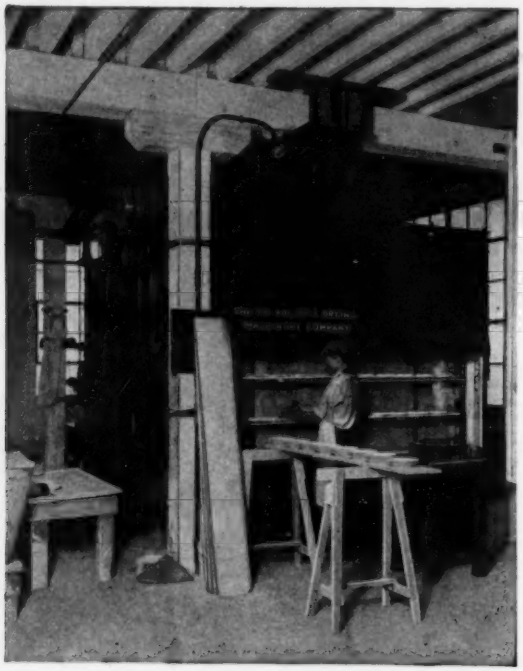

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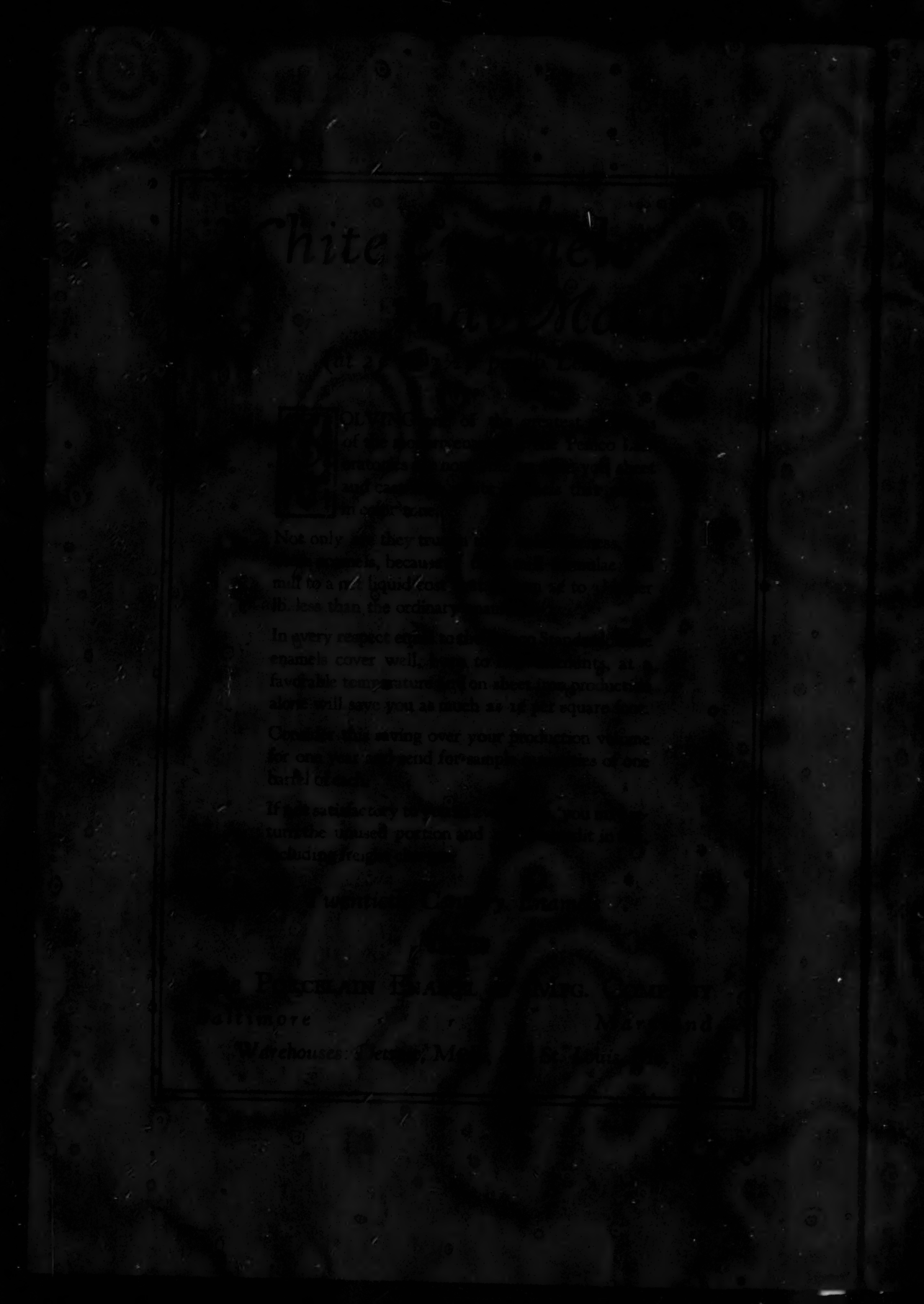
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